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PROTEIN LEVEL AND BALANCE
IN SWINE DIETS

by



ARNOLD BRIAN PIERCE

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Protein Level and Balance in Swine Diets" submitted by Arnold Brian Pierce, B. Sc., in partial fulfillment of the requirements for the degree of Master of Science.

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ABSTRACT

Three experiments were designed to study the effects of dietary protein level and protein (amino acid) balance on growth response and carcass quality in market pigs from 5 weeks of age to slaughter (90 kg). Diets containing selected levels of protein were fed in starting, growing and finishing periods, in combinations of 20, 16 or 13 % dietary protein or 13 % protein supplemented with 0.1 % L-lysine HCl or 0.2 % DL-methionine and 0.1 % L-lysine HCl. Other factors considered were sex, and in Experiment II, breed. Metabolism trials were also conducted in Experiment II to assess the effects of dietary protein level and balance on nitrogen digestibility and retention and digestible and metabolizable energy. Experiments I and II were conducted at The University of Alberta Edmonton Research Station, while Experiment III was conducted at the Agricultural and Vocational College, Olds, Alberta.

Dietary protein level did not have a consistent influence on feed intake, gain and feed conversion efficiency in the three experiments. Feed intake and gain were generally depressed on low protein diets with less effect as the pigs became heavier. Pigs fed low protein diets throughout exhibited the most efficient feed conversion in later periods of growth. The reverse was true for pigs fed higher levels of protein. Supplements of lysine or methionine and lysine improved feed intake but did not increase it to a level equal to that of pigs fed higher levels of protein, especially in the starting period. Gain and efficiency of feed conversion were improved an equivalent amount by lysine and methionine or lysine supplements.

There were few significant differences related to nitrogen digest-

ibility and retention or to digestible or metabolizable energy. On a daily basis, more nitrogen was retained in pigs fed high protein diets.

Slaughter age was increased for pigs fed low protein sequence diets in Experiments I and II but not in Experiment III. Slaughter age was decreased an equivalent amount by supplements of methionine and lysine or lysine alone. Carcass weight, dressing %, total backfat, ham/carcass (%), lean in ham face (%), lean area ham/ham weight, ROP ratings and grade index were generally not affected by treatment. In Experiment I, loin area was not affected by treatment but in Experiment II, loin area was reduced for pigs fed low protein diets and was improved equally well by supplementation with methionine and lysine or lysine alone.

Barrows generally ate more, gained faster and were less efficient in feed conversion than gilts, except in the starting period where gilts ate and gained at a level at least equal to barrows. Gilts had consistently superior carcasses when compared with barrows.

Hampshire x Yorkshire pigs tended to have higher quality carcasses but reached slaughter weight later than Landrace x Yorkshire pigs.

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INTRODUCTION

An adequate level of high quality protein is frequently the most limiting portion of a mixed swine ration because cereal grains, the base of most swine rations, contain inadequate levels and balance of protein required for optimal growth and maintenance. Until recently, improved level and balance of dietary protein was hopefully achieved by the addition of relatively expensive protein supplements such as fish (herring) meal, soybean meal, or meat meal and more recently, rapeseed meal. There has also been some attempt to improve protein (amino acid) balance by the addition of purified amino acids such as lysine or methionine which may be limiting in the diet. Until recently, however, the cost of production of these purified amino acids has discouraged their routine addition to swine diets. Reduced production costs have resulted in the addition of limiting amino acids to swine diets in an effort to improve amino acid balance, and hence reduce required levels of dietary protein to obtain optimal growth response and high quality carcasses. However, indiscriminate use of these amino acid supplements at excessive levels may induce an amino acid imbalance, with a consequent reduction in feed intake and rate of gain.

Experiments were initiated to study the effects of protein level and balance (as affected by DL-methionine and/or L-lysine HCl supplementation) on feed intake, rate of gain and feed conversion efficiency in market pigs at various periods of growth. The effects of protein level and sequence and amino acid balance on carcass quality were also studied.

LITERATURE REVIEW

Amino Acid Requirements of Growing Pigs

The concept of essential amino acid requirements and the influence of these amino acids when supplemented to diets have been known for some time. For example, Osborne and Mendel (1914) observed that certain proteins that caused nutritive failure in rats could be corrected with the addition of lysine and tryptophan. However, quantitative amino acid requirements for swine were not determined until much later. Mertz, Shelton and Beeson (1949) demonstrated that lysine was an essential amino acid in weanling pig diets. Bell et al (1950) recognized methionine as another essential amino acid for the growth of young swine. Since then, especially in the early 1950's, the quantitative requirements of many of the essential amino acids for the young pig have been determined, for example: tryptophan (Shelton, Beeson and Mertz, 1951); isoleucine (Brinegar et al, 1950a); threonine (Sewell et al, 1952); valine (Jackson, Mertz and Beeson, 1953); phenylalanine (Mertz, Henson and Beeson, 1954); leucine (Eggert et al, 1954); and histidine (Rechcigl et al, 1956).

Since these initial studies, research in the field of amino acid nutrition has evolved through determination of requirements at different periods of growth, interactions between amino acids, calorie:protein ratios and calorie:amino acid ratios to promote maximum growth rate, and to produce lean carcasses. More recently, interest has centered on the routine addition of "synthetic" limiting amino acids to swine rations to improve protein quality.

It is recognized that protein, and more specifically, amino acid requirements per unit of feed decrease progressively as pigs grow older and heavier. However, for practical application, diets are usually form-

ulated for three stages of growth in the market pig: starting period (starter - weaning to approximately 25 kg); growing period (grower - 25 kg to approximately 50 kg); and finishing period (finisher - from 50 kg to market).

The marked effect of the addition of 2.0 % L-lysine HCl to a 23.5 % protein ration containing 0.02 % L-lysine to growing pigs (Mertz, Shelton and Beeson, 1949), was the forerunner of more accurate determinations of lysine requirements at various stages of growth. Brinegar et al (1950b) concluded that the lysine needs of weanling pigs fed diets containing 10.6 % and 22.0 % protein diets were 0.6 % and 1.2 % (5.7 % and 5.5 % of the protein content, respectively). Germann, Mertz and Beeson (1958), in reevaluating the L-lysine requirement of the weanling pig, found it to be 0.70 % of a 15.0 % crude protein (dry matter basis) ration (4.7 % of crude protein or 5.0 % of digestible protein on a dry matter basis). McWard et al (1959) devised a formula for lysine requirements of weanling swine based on dietary protein level:

$$Y = 7.23 - 0.131X \quad \text{where } Y = \text{lysine requirement as a percentage of dietary protein}$$

$$X = \text{percentage of dietary protein}$$

Mitchell et al (1965a) determined the lysine requirement of 5 kg swine to be 1.2 % of the diet (5.5 % of protein in a diet containing 3344 kcal metabolizable energy(ME)/kg and 0.36 - 0.41 % of the diet (3.3 % of dietary protein on a 12.0 % protein ration containing 3219 kcal ME/kg) for 50 kg pigs.

The National Academy of Sciences (1968) sets the lysine requirement of the pig based on three weight ranges: 5 - 10 kg (1.20 % lysine in a 22 % protein ration); 20 - 35 kg (0.70 % lysine in a 16 % protein ration); and thereafter at 0.50 % lysine in a 14 % protein ration, with protein

content based on cereal grains in all cases.

It would appear that the lysine requirement of growing swine may be expressed as a percentage of total dietary protein and as such may be set at 3.5 - 5.5 % of the total dietary protein, depending on the caloric density of the diet, and age and weight of the pigs, with higher levels of lysine required during the earlier growth periods. There appears to be an absolute minimum of 0.70 % lysine at later periods of growth with lower levels resulting in reduced growth rate.

Studies of the methionine requirements of young swine have also been clarified since the determination by Bell et al (1950) who found the requirement to be 0.07 - 0.27 % of a diet containing 10.0 % protein. However, many of these studies have been related to the cystine sparing effect on methionine requirements. Curtin et al (1952), using a 22 % protein ration based on soybean protein, glucose and starch, concluded that the methionine-cystine requirement was approximately 0.7 % (3.2 % of the protein in the ration). Kroening, Pond and Loosli (1965) found the methionine-cystine requirement of the 2.7 week old pig to be 0.5 % in a 12.0 % protein ration; 0.6 % in an 18 % protein ration; and 0.7 % in a 25 % protein ration when choline and threonine were not limiting. Becker et al (1955) reported that a level of 0.25 % methionine and 0.17 % cystine (3.33 % of dietary protein) resulted in satisfactory gains in 13 kg pigs. Supplementary levels of 0.3 - 0.4 % DL-methionine inhibited growth. Becker et al (1955) also stated that cystine can meet 40 % of the need for sulphur amino acids. Baker et al (1969a) observed similar gains in the young pig when 56 - 66 % of the sulphur amino acids were from cystine instead of methionine. Above this level, cystine caused an imbalance in the diet. Mitchell et al (1968a) concluded that in 10 kg pigs, cystine can replace 70 % of the need of the total sulphur contain-

ing amino acids.

The National Academy of Sciences (1968) sets the methionine requirement of swine by weight ranges: 5 - 10 kg (0.80 % in a 22 % protein ration); 20 - 35 kg (0.50 % in a 16 % protein ration); and lists no requirement thereafter but states that cystine can satisfy 40 % of the need for methionine.

The overall requirement of methionine for growing swine appears to range from 0.60 % to 0.70 % of the diet with cystine meeting up to 70 % of the requirement.

Energy, Protein, and Amino Acid Relationships in Pig Diets

Since dietary requirements are usually expressed per unit of feed, energy and protein requirements are also usually expressed this way. This has resulted in the development of calorie - protein (C/P) ratios; and more recently, calorie - amino acid ratios, usually with lysine being considered as the first limiting essential amino acid.

Abernathy and Sewell (1958) observed a highly significant depression in rate of gain when L-lysine HCL was added at a level of .1 % to a 14 % or 18 % protein diet; but the effect of this depression was reduced as the caloric density of the diet increased (by the addition of 5 or 10 % stabilized tallow). Increased caloric density of the ration also resulted in increased gains and improved feed conversion.

A study conducted by Clawson et al (1962) also related the effects of the addition of 5 or 10 % added fat (stabilized yellow grease) when diets containing graded levels of 10 - 18 % protein with a constant ratio of amino acids were fed to growing swine. Feed consumption was determined mainly by the energy level and not protein level and was reduced ($P < .05$) with added levels of fat. Growth rate, especially during the first 28 days was influenced ($P < .05$) by the C/P ratio; with the narrowest ratio

(26 kcal digestible energy (DE)/g protein in the mixed ration) producing the fastest gains but this difference was not significant by slaughter weight (approximately 98 kg).

Similar experiments were conducted by Greeley et al (1964). In a first experiment, growing pigs were fed diets for two week intervals containing 0, 5, 10 or 15 % stabilized lard, tallow or crude corn oil. Daily intake of dry matter was not depressed by addition of the fat. No mention is made of a C/P ratio but the effects are inferred indirectly. Apparent digestibility increased with increased protein level, and apparent digestibility of energy was increased with increased level of dietary protein. Increased levels of dietary tallow resulted in highly significant increases in daily consumption of DE and gain per unit of digestible protein consumed, but a significant decrease in efficiency of conversion of DE to gain.

Wagner et al (1963) also studied protein - energy relationships with growing swine. Diets containing 25, 19, or 13 % protein were fed at two energy levels: 2880 or 3610 kcal ME/kg (Diggs et al, 1959). Decreasing protein level to 13 % increased rate of gain but reduced feed efficiency; with the 25 % protein ration being most efficient. Increasing energy level improved efficiency of feed conversion and increased gain. In general, feed conversion was improved by increasing either the energy level or the protein level in the diet.

A calorie - protein ratio is suggested by Robinson, Morgan and Lewis (1964a). Diets were offered in combinations of approximately 3260, 3150, 2860 or 2650 kcal DE/kg and 20, 18, 16 or 14 % protein. Daily weight gain and feed conversion was found to be superior when diets contained 18 % crude protein at 3300, 3080 or 2640 kcal DE/kg and 20 % crude protein in a diet with 2860 kcal DE/kg.

There are also indications that requirements may be expressed as energy/unit lysine. Mitchell et al (1965b) fed a corn - sesame diet set at 16.0 % dietary protein containing varying ME levels of 2926, 3267, or 3718 kcal/kg and .54, .64, .74, .94, or 1.14 % lysine. Mitchell et al (1965b) concluded that for maximum rate of gain and feed efficiency in the 16 - 22 kg pig, the lysine requirement in the diet was .23 %/1000 kcal ME; and for the 13 kg pig, the requirement was .80 and .90 % for diets containing 2926 and 3718 kcal ME/kg respectively for maximum feed efficiency. These requirements are similar to those determined by McWard et al (1959).

Anderson and Bowland (1967) concluded that a calorie:lysine ratio of 4000:1 kcal DE/kg/% lysine was adequate for maximum efficiency of feed utilization but that a ratio of at least 3500:1 was needed for maximum gain. This is roughly equivalent to values quoted by Robinson and Lewis (1964) and McWard et al (1959).

Protein Level and Amino Acid Balance

Feed Intake

Protein level, or more correctly, amino acid level and balance has been shown to influence feed intake.

A very extensive study between protein level, amino acid balance, and energy relationships in pigs was conducted by Clawson (1967). Pigs fed a high protein diet consumed more ($P < .05$) ME than those on low protein diets. Pigs fed supplementary fat at 10 or 20 percent consumed less ($P < .01$) than pigs on a similar diet containing no supplementary fat. Pigs fed low protein diets did not compensate for low protein intake by consuming feed in excess of energy requirements. Protein level and caloric density affected daily feed independently and in opposite directions. Less feed/gain was required when the higher level protein was fed. Daily caloric intake

was greatly depressed by increasing caloric density when protein level was inadequate and was even more depressed when the diet contained an amino acid imbalance. Daily feed intake was not significantly influenced by protein level as long as amino acid balance was adequate. Depression of caloric intake resulting from increased caloric density was not evident when low protein diets containing high quality protein were fed. This suggested that the adequacy of essential amino acids in the diet may have more influence on daily intake than level of protein per se.

A depression in feed intake has been observed for chicks (Shapiro and Fisher, 1962; Fisher et al, 1960), rats (Leung, Rogers and Harper, 1968; Rogers, Tannous and Harper, 1967; and Harper, 1959) and pigs (Devilat, Pond and Miller, 1970; Baker et al, 1969b; and Becker et al, 1955) fed amino acid imbalanced diets. There have been several suggestions as to how this depression occurs. Nasset, Ridley and Schenk (1967) suggested that a reduction in food intake in rats fed imbalanced amino acid diets was due to the changes in the blood amino acid pattern which alters the excitability of the ventro-medial hypothalamus controlling satiety.

Ellison and King (1968) tested the hypothesis that reduced food intake following ingestion of an amino acid mixture was a consequence of abnormally low tissue concentration of free limiting amino acids in rats. A depression in concentration of the limiting amino acid balance in amino acid deficient diets occurred 3 - 5 hours after ingestion; and a reduced appetite occurred 20 hours later. When placed back on a corrected diet, there was a lag of 18 - 20 hours between correction of tissue levels and improved appetite. It was suggested that tissue levels of limiting amino acids do not affect appetite directly, but rather appetite depression is related to some consequence of these tissue concentrations.

Peng and Harper (1970) related the effect of dietary amino acid patterns to plasma amino acid concentrations in rats. They concluded that elevated concentration of plasma amino acids that cannot be channelled into protein synthesis may serve as a satiety signal for a food regulating mechanism, causing reduced food intake. Diets containing essential amino acids were found to suppress intake more than non-essential amino acid based diets since enzymatic activity was slower for degradation of these essential amino acids. Increased capacity for amino acid degradation in rats over time enabled them to consume more of the imbalanced diets before the stimulus initiating intake depression was activated.

It has been shown that rats (Rogers, Tannous and Harper, 1967) and pigs (Devilat, Pond and Miller, 1970) prefer a protein - free diet to an amino acid imbalanced diet. This could be because of the effect of imbalanced amino acid diets on a satiety centre (Peng and Harper, 1970; Nasset, Ridley and Schenk, 1967).

Rate of Gain and Feed Conversion

Feed conversion, and especially average daily gain (ADG), appear to be affected by dietary protein level and balance.

Increased dietary protein level has been shown to increase ADG (Dent et al, 1970; Wyllie et al, 1969; Davey and Morgan, 1969; Young et al, 1968; Jurgens et al, 1967; Seerley, Poley and Washlstrom, 1964; Seymour et al, 1964; Bowland and Berg, 1959) have no effect on ADG (Meade et al, 1969a; Meade et al, 1969b; Blair et al, 1969; Meade, Dukelow and Grant, 1966; Reimer and Meade, 1964; Robinson, Morgan and Lewis, 1964b) or cause a decline in ADG (Wagner et al, 1963).

Similar variable findings of the effects of amino acid supplements on ADG have been determined. Improved ADG with supplemental lysine has occurred (Dent et al, 1970; Washlstrom, Taylor and Seerley, 1970; Nielson

et al, 1963; Cahilly et al, 1963; Clawson, Barrick and Smart, 1963; Bowland, 1962) and has also had no effect (Stockland, Meade and Nordstrom, 1971; Gallo and Pond, 1968; Jurgens et al, 1967; Meade, Dukelow and Grant, 1966). Simultaneous lysine and methionine supplementation has been shown to improve ADG (Baker et al, 1969a; Bayley and Summers, 1968; Meade et al, 1965). Diets supplemented with tryptophan as well as lysine and methionine have shown a similar effect (Kornegay, Mosanghini and Snee, 1970). However, no improvement in ADG with lysine and methionine supplementation has also been observed (Stockland, Meade and Nordstrom, 1971; Meade, Dukelow and Grant, 1966).

It is generally accepted that increased dietary protein levels improve feed conversion efficiency (Wyllie et al, 1969; Bell and Voldeng, 1968; Young et al, 1968; Jurgens et al, 1967; Hale and Southwell, 1967; Wagner et al, 1963; Bowland and Berg, 1959). However, increased dietary protein level has also had no effect on feed conversion efficiency (Meade et al, 1969b; Meade, Dukelow and Grant, 1966; Reimer and Meade, 1964).

As in ADG, amino acid supplements have had variable effect on feed conversion efficiency. Feed conversion has been improved with supplemental lysine (Wahlstrom, Taylor and Seerley, 1970; Nielson et al, 1963; Cahilly et al, 1963; Vipperman et al, 1963) or had no effect (Stockland, Meade and Nordstrom, 1971; Gallo and Pond, 1968; Jurgens et al, 1967; Meade, Dukelow and Grant, 1966). Simultaneous lysine and methionine supplementation has been generally beneficial in improvement of feed conversion efficiency (Baker et al, 1969a; Bayley and Summers, 1968; Meade et al, 1965), but has also been shown to have no effect on feed conversion efficiency (Stockland, Meade and Nordstrom, 1971; Meade, Dukelow and Grant, 1966).

Increased dietary protein levels generally increase ADG, but may de-

crease or have no effect on ADG. The difference in results between experiments may be associated with the absolute levels of protein in the basal diets prior to supplementation, or to overall amino acid balance in the basal diets. Supplemental methionine and/or lysine may improve ADG or have no effect; depending on dietary protein level and age of the pigs. Feed conversion efficiency is similarly affected. Generally, simultaneous lysine and methionine supplementation does not improve ADG and feed conversion above that of the addition of lysine alone.

Carcass Characteristics

Dietary protein level and balance or sequence has a profound effect on quality in hog carcasses, as determined by various criteria.

Both positive and negative effects have been observed on backfat thickness as influenced by dietary protein. Increased dietary protein level has been found to reduce backfat thickness (Hale and Southwell, 1967; Greer et al, 1965; Seerley, Poley and Wahlstrom, 1964; Seymour et al, 1964; Wagner et al, 1963). No effects on backfat thickness by increased dietary protein level have been found by Jurgens et al (1967), or Clawson et al (1962). Carcass backfat was found to increase with supplementary lysine by Cahilly et al (1963) but not to be altered by Meade, Dukelow and Grant (1966).

Similar conclusions have been made on loin eye muscle area (loin area). Increased dietary protein levels have been shown to increase loin area (Bell and Voldeng, 1968; Hale and Southwell, 1967; Seerley, Poley and Wahlstrom, 1964) or have no effect on loin area (Meade, Dukelow and Grant, 1966; Clawson et al, 1962). Increased loin area with supplemental lysine has been found by Cahilly et al (1963), Vipperman et al (1963), Clawson, Barrick and Smart (1963) but no change in loin area was observed by Gallo and Pond (1968).

Dressing percentage and carcass leanness have been shown to be variably affected by dietary protein levels. Dressing percentage does not appear to be greatly affected by dietary protein level (Meade et al, 1969a; Meade et al, 1969b, Jurgens et al, 1967) but has been shown to be affected by dietary protein level by Wagner et al (1963). A reduced dressing percentage with increased lysine levels has been shown by Jurgens et al (1967). Increasing dietary protein level generally increases carcass leanness (Waldern, 1964; Nielson et al, 1963; Wagner et al, 1963; Bowland and Berg, 1959) but has been shown to have no effect by Meade, Dukelow and Grant (1966). Increased carcass leanness with supplemental lysine has been shown by Nielson et al (1963) but no effect was observed by Meade, Dukelow and Grant (1966).

Gilts are generally considered as producing higher quality carcasses (Skitsko and Bowland, 1970a; Robinson and Lewis, 1964) with less backfat (Friend and MacIntyre, 1970; Wagner et al, 1963; Bowland and Berg, 1959) and greater total leanness (Cahilly et al, 1963; Nielson et al, 1963; Wagner et al, 1963; Bowland and Berg, 1959) than carcasses from contemporary castrate males (barrows). Gilts have also been shown to have longer carcasses than barrows (Hale and Southwell, 1967; Robinson and Lewis, 1964; Bruner and Swiger, 1968) but this is not considered to reflect the value of the carcass (Pearson et al, 1970).

Increased dietary protein level or balance normally improves carcass quality, with less effect being observed at higher dietary protein levels. Females are recognized as having the ability to produce higher quality carcasses in comparison with barrows under a given dietary protein regimen.

Influence of Breed or Type of Pig

Breed or type of pig has also been shown to exert an effect on growth response and carcass quality of pigs fed varying levels of protein.

McConnell, Barth and Griffin (1971) selected lean or fat - type feeder pigs to compare influences of dietary protein level on growth response and carcass quality. From weaning to 57 kg liveweight, pigs were fed a high protein (18 %) or low protein (14 %) growing ration. At this weight, they were put on a finishing ration of high protein (16 %) or low protein (14 %) level. It was concluded that to 41 kg, lean or fat - type hogs require a similar level of dietary protein. Lean - type hogs had an increased need for protein past this weight in comparison with fat - type hogs, as evidenced by the fact that increasing protein levels improved carcass quality in lean - type hogs only. They also concluded that the protein intake of lean - type hogs should be constant from 41 to 70 kg and then decline, whereas for fat - type hogs, protein level should gradually decline at weights past 41 kg.

Davey and Morgan (1969) slaughtered pigs at different ages to compare the effects of dietary protein level on lean or fat - type pigs. Protein level was set at 20 % or 12 % and pigs were slaughtered at 84, 112, 154, 168, 210 or 224 days of age. Pigs fed the 20 % protein diet gained faster ($P < .01$) to 140 days of age than those on the 12 % protein diet but at 196 days of age gains were no longer significantly different but a similar trend was observed. There were no significant differences in gain between types of pigs. On a weight basis, the amount of lean in fat - type hogs and lean - type hogs at the 12 % dietary protein level was essentially the same, while the weight of lean on lean - type pigs at 20 % dietary protein level was consistently greater than that of the fat - type pigs. This suggested to Davey and Morgan (1969) that a difference exists among the lines of swine in their need for dietary protein and their ability to make use of this protein to form body tissues.

Bayley and Summers (1968) noted a differential breed response to in-

creased protein level (13 % to 16 %) wherein Lacombe and Yorkshire pigs showed improved gain with increased protein level, but Landrace and crossbred pigs did not.

Bruner and Swiger (1968) observed that Duroc pigs had the lowest feed requirements, followed by Yorkshire and Landrace. Poland China, Hampshire and Spotted pigs were similar in feed requirements and higher than the other three breeds. Aunan et al (1961) also compared breeds. Duroc and Yorkshire pigs were shown to have a differential growth response to protein level sequence. A starting - growing diet was fed to 57 kg liveweight and a finishing ration was fed thereafter. Dietary protein level sequences were 16 - 11, 14 - 11, or 12 - 12 %. Duroc pigs gained faster ($P < .01$) overall but had more backfat ($P < .01$). Feed conversion was similar between breeds.

A very extensive study of the effects of breed on growth and carcass characteristics was conducted jointly by Richmond and Berg (1971) and Skitsko and Bowland (1970a, 1970b). Pigs of Duroc x Yorkshire (DY), Hampshire x Yorkshire (HY), and Yorkshire x Yorkshire (YY) breeding were fed diets of 3652 kcal DE/kg or 2757 kcal DE/kg containing 19.9 % or 15.3 % protein respectively. Skitsko and Bowland (1970a) reported that DY and HY pigs gained faster ($P < .01$) and had a better ($P < .01$) feed conversion than YY pigs. Breeding group did not significantly affect apparent digestible energy, apparent digestible nitrogen, ME or N-retention (Skitsko and Bowland, 1970b). Skitsko and Bowland (1970a) also reported that YY pigs had a lower dressing percentage ($P < .05$) but longer carcasses ($P < .01$) than DY and HY pigs. HY pigs had less total backfat ($P < .05$) than DY and YY pigs. Loin area was smallest ($P < .01$) in YY pigs; was increased ($P < .01$) in DY pigs; and was again larger ($P < .01$) in HY pigs. Richmond and Berg (1971) compared carcasses of the three

breeding groups based on tissue growth. A normal pattern of tissue growth was shown to occur, bone growth being relatively slow and muscle growth relatively fast. Fat (subcutaneous, intermuscular and body cavity fat plus loose connective tissue) deposition paralleled muscle growth from 68 to 91 kg; after which fat growth was faster. YY pigs were older at slaughter (187 days) than HY or DY pigs which were equal (173 days) in age at slaughter. HY pigs had greater weight of muscle per day of age than DY or YY pigs but were intermediate in fat per day of age with DY pigs having the greatest fat per day of age.

As evidenced above, growth response and carcass quality between breeds can be considered as being the result of 'type' of pig rather than breed per se. Results suggest that lean - type pigs have the inherent ability to utilize higher levels of dietary protein more efficiently in the production of lean in comparison with fat - type pigs.

Influence of Sex

Different responses to dietary protein level or balance have been observed between boars, gilts and barrows.

Bayley and Summers (1968) studied the effect of protein level and lysine-methionine supplementation based on corn - soybean meal (corn - SBM) diets. In a first experiment boars and gilts were fed two levels of dietary protein: 13 % or 16 %. In a second experiment boars, gilts and barrows were fed combinations of 12 % or 14 % protein diets containing two levels of lysine addition (0 and .1 % L-lysine HCl) and two levels of methionine supplementation (0 and .05 % DL-methionine). In the first experiment, boars grew significantly faster than gilts and responded to increased protein with increased gain whereas the gilts did not. However, gilts had better overall conversion. In the second experiment, barrows gained more on the 12 % protein, unsupplemented diet than either

the boars or gilts but did not respond to either increased protein levels or amino acid supplements; gilts responded to supplementation of the 12 % protein diet or increased protein level from 12 % to 14 % protein but did not respond to lysine and methionine supplementation of the 14 % protein diet. Boars responded to an increase in protein content of the diet and also to the combined supplement of both diets.

Blair and English (1965) also related the effects of 'sex' (boars, gilts and barrows) on growth. In comparison of boars to barrows, daily weight gains were higher ($P < .001$); feed intake was lower ($P < .05$); and feed conversion better ($P < .001$) in boars. In comparison of boars with gilts; daily weight gains were better ($P < .001$) as was feed conversion ($P < .01$) in boars but there were no significant differences in feed intake. Daily feed intakes were lower ($P < .01$) and feed conversion was better ($P < .001$) in gilts than barrows. There were no significant differences in daily weight gain between gilts and barrows, however.

Similar conclusions were made by Bowland and Newell (1971) in comparison of boars, barrows and gilts. Pigs were fed an 18 % protein diet throughout, or a 16 - 13 % protein sequence diet in starting - growing and finishing periods respectively. Boars ate less than gilts or barrows and had the best feed conversion. Barrows had the highest feed intake, but the poorest feed conversion efficiency. Boars and gilts obtained more benefit from higher dietary levels of protein than did barrows.

Several comparisons have also been made between barrows and gilts. Young et al (1968) noted that feed intake was greater in barrows than gilts. Barrows have also been shown to gain faster than gilts (Bruner and Swiger, 1968; Wagner et al, 1963; Mulholland, Erwin and Gordon, 1960; Bowland and Berg, 1959). Gilts have been shown to be more efficient than barrows in feed conversion by Bruner et al (1958) but only slightly

more efficient by Wagner et al (1963) and Bowland and Berg (1959). Dent et al (1970) noted that gilts were more efficient converters of lysine and energy into liveweight and lean meat than were barrows.

The overall concensus appears to be that boars are most responsive to an increase in protein level and that barrows are least responsive with gilts being intermediate. Although barrows have the highest feed intake, the efficiency of feed conversion is usually poorer than that of boars or gilts. Boars generally gain faster than gilts and have a better feed conversion.

Nitrogen Retention Studies

N-retention has been shown to be influenced by dietary protein level, amino acid supplementation and by weight and age of the experimental pigs.

Rutledge, Hanson and Meade (1961) found that N-retention significantly increased with increasing dietary protein levels (16, 20, 24 or 28 %) in pigs 3 to 8 weeks of age but the percentage of apparently absorbed nitrogen (N) retained by the pig decreased. It appeared that the percentage of dietary protein required to promote satisfactory gains in suckling pigs was somewhat less than that required to promote satisfactory N-retention. It was also concluded that pigs weaned at 3 weeks of age require at least 20 % protein of high quality to promote maximum N-retention during the early stages of the subsequent growth periods. Improved N-retention has also been observed by increased dietary protein level by Likuski, Bowland and Berg (1961) and Meade and Teter (1956).

Both positive and negative effects have been observed on N-retention upon supplementation with amino acids in an effort to improve protein balance. Improved N-retention with supplemental lysine has been observed (Welch, Cordts and Van der Noot, 1966; Soldevila and Meade, 1964) as well

as negative effects on N-retention upon supplementation with lysine (Welch, Cordts and Van der Noot, 1966; Meade and Teter, 1956; Meade et al, 1956a). Both positive and negative effects have been observed with tryptophan supplementation. Increased N-retention with supplemental tryptophan was observed by Welch, Cordts and Van der Noot (1966) and a decreased level of N-retention was found by Meade (1956a) with supplemental tryptophan. Supplementation of diets with methionine has generally had no effect on, or caused a decline in, N-retention (Bowland and Grimson, 1970; Soldevila and Meade, 1964; Meade, 1956a; Meade, 1956b).

The positive and negative effects of amino acid supplementation can be explained by the fact that the majority of positive responses have been on low, poorly balanced protein diets. Therefore, a positive response would be expected. At higher dietary protein levels, however, intakes of essential amino acids may be adequate and so no response to amino acid supplementation would be expected.

In some cases, a negative response to amino acid supplementation has been the result of an amino acid imbalance (Meade and Teter, 1956; Meade, 1956b) or inadequate total N (Meade and Teter, 1956). This lack of response could be further explained by Mitchell et al (1968a) who concluded that the young pigs uses dietary N best when essential and non-essential amino acids each furnished about 50 % of the total dietary N. Digressions from this could have an effect on N-retention.

Apparent digestibility of crude protein has also been shown to be higher in pigs fed higher protein diets (McConnell, Barth and Griffin, 1971; Standish and Bowland, 1967; Greeley et al, 1964; Kuryvial and Bowland, 1962).

The age of pigs has been demonstrated to affect protein digestibility and N-retention. Increased protein digestibility has been shown with in-

creased age by McConnell, Barth and Griffin (1971); Anderson and Bowland (1967) and Robinson, Morgan and Lewis (1964b). In contrast, reduced N-retention with increased age has been shown to occur (McConnell, Barth and Griffin, 1971; Robinson, Morgan and Lewis, 1964b; Likuski, Bowland and Berg, 1961).

N-retention is generally improved by increased level or balance of dietary protein, with less or no effect at higher levels of dietary protein. Amino acid imbalances may interfere. Apparent digestibility of crude protein increases with increased protein levels and also with age. N-retention, on a percentage of intake basis, however, generally decreases with increased weight or age of the pig. Absolute levels of N-retention seem to remain relatively constant from 20 kg to 90 kg live-weight (Bowland et al, 1970).

Plasma Amino Acid Studies

Dietary protein levels have been shown to influence plasma amino acid levels (Olsen et al, 1959; Purchal et al, 1962). This observation has encouraged research in relations between dietary amino acid levels and plasma amino acid concentration.

Stockland, Meade and Nordstrom (1970) concluded that the supplementation of limiting dietary amino acids reduced plasma levels of amino acids not included in the supplements and increased the plasma levels of amino acids supplemented but to a lesser degree than the amount of amino acids added at the dietary level. Lowered plasma amino acid levels inferred an improved amino acid balance reflected in an improved rate of gain. In a follow-up study, Stockland, Meade and Nordstrom (1971) supplemented corn-SBM diets for growing pigs with .20 % L-lysine HCl, .25 % methionine and/or .10 % tryptophan. Tryptophan and methionine, alone or in combination, increased concentration of plasma - free amino acids, re-

ardless of lysine supplements. Plasma - free lysine decreased with supplementation of the diet with methionine and this decrease was associated with increased rate of gain.

Grimble and Whitehead (1969) fed synthetic amino acid deficient diets to pigs and found that amino acid levels were not elevated until growth was impaired and total serum protein and albumin began to fall. Similar observations were made again by Grimble and Whitehead (1970); until growth was markedly impaired, reduction of dietary protein had no significant effect on serum amino acid pattern.

Mitchell et al (1968b) studied the relationship between N-retention and plasma - free amino acids in the young pig. They found that the addition of a particular amino acid to the diet did not increase the content of this amino acid in the plasma until the dietary requirement was met. When excessive levels of an amino acid were present in the diet, plasma levels of this amino acid increased.

Typpo et al (1970); Nordstrom et al (1970) and Windels et al (1971), all reported that concentration of plasma amino acids at intervals after feeding, especially 8 hr, were sensitive to dietary levels of amino acids. Stockland and Meade (1970) and Windels et al (1971) noted that as ADG increased there was increased removal of amino acids from plasma supposedly for protein synthesis. An excellent review of relations between free amino acids in the body is provided by Munro (1970) who also discusses the effects of protein, carbohydrate, fat, vitamins and minerals which affect the fate of absorbed amino acids.

Plasma amino acid levels tend to reflect dietary amino acid level, balance, and availability. Improvement of these dietary criteria results in a better balanced profile of free amino acids in the plasma and often an improved rate of gain. Feeding a diet poorly balanced in amino acids

tends to cause elevation of free amino acids in the plasma except for the limiting amino acids which tend to be depressed.

Pigs require a certain level of each essential amino acid for optimal growth, expressed either per unit of total diet, per unit of energy, or per unit of protein. "Acceptable" feed intake, gain and feed conversion may be achieved over a range of these requirements. Above certain limits, however, disproportionate ratios result in a depression of feed intake, gain, or feed conversion or all three and may also produce inferior carcasses. By improving the ratios of amino acids usually limiting in cereal-based rations (usually lysine and/or methionine), optimal growth response may again be achieved along with improved carcass quality.

EXPERIMENTAL

Objectives

Experiments were designed to relate the effects of dietary protein level and balance as influenced by amino acid supplementation on feed intake, rate of gain, efficiency of feed conversion, protein and energy utilization, and carcass quality of growing pigs.

Methods and Procedures

Introduction

The author's advisor conducted the first experiment (Experiment I) in the winter and spring of 1969-70. The author conducted a similar experiment (Experiment II) in the summer and fall of 1970. This second experiment also included a metabolism trial to study digestible and metabolizable energy, digestible protein and N-retention. A related experiment (Experiment III) was conducted as a co-operative project by S. B. Wilton, Co-ordinator, Livestock Programs, O.V.A.C., Olds, Alberta.

Experimental Diets

Formulation and composition of experimental diets are given in Table 1. The experimental design outlining diets fed for the starting, growing, and finishing periods (starter, grower and finisher, respectively) is summarized in Table 2.

Experiment II was similar to Experiment I except that there was an extra treatment (#6 - 13 % protein + lysine) in Experiment II. Also, unlike Experiment I, amino acid supplements were fed in the grower and finisher as well as the starter ration. Experiment III was analogous to Experiment I except that the amino acid supplement (lysine and methionine) was fed in treatment 5 in the grower and finisher.

Experimental diets for Experiments I and II were mixed and bagged at The University of Alberta Edmonton Research Station elevator and stored

Table 1. Formulation and composition of experimental diets

Diet #	1	2	3	4	5
Fed in Experiments	I,II,III	I,II,III	I,II,III	I,II,III	II
Calculated protein (%)	20	16	13	13	13
<u>Ingredients</u>					
Barley	510.00	627.50	716.00	713.00	714.00
Wheat	200.00	200.00	200.00	200.00	200.00
Soybean meal (44 %)	240.00	120.00	30.00	30.00	30.00
Herring meal (72 %)	20.00	20.00	20.00	20.00	20.00
L-lysine (feed grade) ¹	0.00	0.00	0.00	2.00	2.00
DL-methionine (feed grade) ²	0.00	0.00	0.00	1.00	0.00
Bonemeal or dical.-phosphate	13.00	13.50	14.00	14.00	14.00
Calcium carbonate	6.00	8.00	9.00	9.00	9.00
Zinc sulphate	0.25	0.25	0.25	0.25	0.25
Iodized salt	4.00	4.00	4.00	4.00	4.00
Trace mineral mix ³	2.50	2.50	2.50	2.50	2.50
Vitamin B mix ⁴	2.50	2.50	2.50	2.50	2.50
Vitamin B ₁₂ mix ⁵	1.00	1.00	1.00	1.00	1.00
Vitamin A premix ⁶	+	+	+	+	+
Vitamin D premix ⁷	+	+	+	+	+
Vitamin E (Myvamix 20) ⁸	0.25	0.25	0.25	0.25	0.25
Aureo SP-250	0.50	0.50	0.50	0.50	0.50
TOTAL: (kg)	1000.00	1000.00	1000.00	1000.00	1000.00

Calculated Composition:

Digestible energy	kcal/kg	3160	3120	3100	3100	3100
Calcium	%	0.67	0.71	0.74	0.74	0.74
Phosphorus	%	0.76	0.74	0.73	0.73	0.73
Lysine	%	1.10	0.80	0.57	0.71	0.71
Methionine + cystine	%	0.60	0.51	0.43	0.53	0.43

¹ L-lysine mono HCl (98 %), Pfizer Co. Ltd. Montreal, Quebec.

² DL-methionine (99 %), Degussa, West Germany.

³ Supplies the following per metric ton of mixed feed: 5.83 g cobalt carbonate, 61.93 g copper sulphate, 3.3 g ethylene diamine dihydroiodide, 594 g ferrous carbonate, 120.67 g manganous oxide, 7.48 g zinc oxide, and 167.09 g limestone.

⁴ Supplies the following per metric ton of mixed feed: 11.11 g riboflavin, 22.22 g calcium pantothenate, 50.5 g niacin, 55.66 g choline chloride, and 1.65 g folic acid.

⁵ Supplies 19.80 mg vitamin B₁₂ per metric ton of mixed feed.

⁶ To supply 4,400,000 I.U. vitamin A per metric ton of mixed feed.

⁷ To supply 550,000 I.U. vitamin D per metric ton of mixed feed.

⁸ Provides 11,000 I.U. vitamin E (α -tocopherol) per metric ton of mixed feed.

⁹ Supplies 22 g chlortetracycline, 22 g sulfamethazine, and 11 g penicillin (from procaine penicillin) per metric ton of mixed feed. Cyanamid of Canada Ltd.

Table 2. Experimental design for Experiments I, II and III summarizing the calculated protein levels in diets

Experiment	Treatment	Period: Starter ¹ (1-6 wk)	Grower (6-12 wk)	Finisher (12 wk-market)
I	1	20	16	13
	2	20	13	13
	3	16	16	16
	4	13	13	13
	5	13+1+m ²	13	13
II	1	20	16	13
	2	20	13	13
	3	16	16	16
	4	13	13	13
	5	13+1+m ²	13+1+m ²	13+1+m ²
	6	13+1 ³	13+1 ³	13+1 ³
III	1	20	16	13
	2	20	13	13
	3	16	16	16
	4	13	13	13
	5	13+1+m ²	13+1+m ²	13+1+m ²

- ¹ Approximate length of time pigs were fed each dietary protein level.
² Supplemented with L-lysine and DL-methionine.
³ Supplemented with L-lysine.

in the barn where they were fed. The sources of ingredients for the two experiments were not the same. Experimental diets for Experiment III were commercially mixed and contained different ingredient sources to those used in either Experiments I or II.

Analyzed protein content of the experimental diets is illustrated in Table 3.

Amino acid composition of experimental diets used in Experiment II is given in Table 4. Amino acid assays were not conducted on the diets fed in Experiments I and III.

Table 3. Analyzed¹ protein levels of experimental diets on an air dry basis

Diet #	1	2	3	4	5
Calculated protein level (%)	20	16	13	13	13
Experiment I	20.0	16.6	13.9	13.9	---
Experiment II	22.7	15.7	14.1	14.1	14.1
Experiment III	19.2	16.3	14.0	14.0	---

¹ AOAC, 1965. Based on N x 6.25.

Actual experimental procedure is discussed on the basis of each experiment.

Experimental Design

A. Experiment I

1. Growth Studies and Carcass Evaluation

Experiment I consisted of two replicates. Replicate 1 was started on November 19, 1969 and pigs averaging 35.5 days of age and 6.9 kg live-weight were used. In replicate 2, initiated November 27, 1969, pigs averaged 35.9 days of age and 6.8 kg liveweight at time of allotment. Pigs were weaned at three weeks of age and kept on a standard starting diet until allotment. Prior to weaning, all pigs were treated in a manner as described by Grimson (1969). Within each replicate, 40 pigs of mixed breeding (Hampshire x Yorkshire, Duroc x Lacombe-Yorkshire, Lacombe x Lacombe-Yorkshire or Yorkshire) were allotted on the basis of sex and weight to the five treatments (Table 1). After allotment, pigs were self-fed in groups of four with gilts and barrows in different pens. All pigs were fed the starting diets as outlined in Table 2, and changed to the growing diet after 6 weeks at approximately 77 days of age, and

Table 4. Amino acid composition¹ of experimental diets (g amino acid/100 g mixed feed) on an air dry basis for Experiment II

Diet #	1	2	3	4	5
<u>Amino Acids</u>					
Alanine	0.98	0.64	0.62	0.58	0.56
Arginine	1.35	0.78	0.74	0.71	0.70
Aspartic Acid	2.00	1.14	0.97	0.93	0.90
Cystine	0.51	0.43	0.32	0.32	0.35
Glutamic Acid	4.63	3.64	3.30	3.23	3.17
Glycine	1.00	0.66	0.64	0.62	0.61
Histidine	0.54	0.35	0.31	0.31	0.31
Isoleucine	0.90	0.57	0.52	0.49	0.50
Leucine	1.60	1.08	0.99	0.98	0.94
Lysine	1.24	0.69	0.62	0.77	0.72
Methionine	0.34	0.23	0.24	0.30	0.21
Phenylalanine	1.07	0.71	0.67	0.67	0.64
Proline	1.52	1.32	1.21	1.21	1.15
Serine	1.05	0.70	0.63	0.62	0.61
Threonine	0.81	0.54	0.96	0.48	0.48
Tyrosine	0.55	0.35	0.31	0.31	0.29
Valine	1.03	0.71	0.67	0.64	0.63
Ammonia	0.50	0.41	0.37	0.34	0.37
Total	21.62	14.95	14.09	13.51	13.14
% lysine of total protein ²	5.46	4.39	4.39	5.46	5.10
% methionine + cystine of total protein ²	3.74	4.20	3.97	4.39	3.97
% cystine of methionine + cystine	60.0	65.2	57.1	51.6	62.5

¹ Represents 94 - 96 % of the total; tryptophan not analyzed. Other amino acids analyzed by Technicon Amino Acid Analyzer, Technicon Instrument Corporation, Chauncy, N.Y., U.S.A.

² Expressed as g amino acid per 16 g N.

then changed to the finishing diet which they were fed until slaughter.

Feed consumption and liveweight were determined on a weekly basis. Weight gain and efficiency of feed conversion were calculated from these data. Individual pigs were marketed for slaughter following the weekly weigh day on which they reached 86 kg (190 lb) liveweight. In each pen, the last pig, regardless of weight, was marketed when the third pig reached slaughter weight. All pigs were slaughtered at Swift Canadian Ltd., Edmonton, Alberta. Standard Carcass Valuation, termed grade index, was determined by total backfat (maximum shoulder fat and maximum loin fat) and warm carcass weight (Canada Department of Agriculture, 1968). R.O.P. measurements and Index (Fredeen, 1966) and the recently revised R.O.P. Index¹ was also determined on all carcasses; however, no sex correction was made on this last measurement of carcass quality.

B. Experiment II

This experiment consisted of two major portions: 1. Growth studies and carcass evaluation, and 2. Metabolism trials. Each portion will be discussed separately.

1. Growth Studies and Carcass Evaluation

Treatment of pigs prior to allotment was similar to that described under Experiment I. Experiment II was also conducted in two replicates. Replicate 1 was started on June 17, 1970 with selected pigs averaging 33.8 days of age and 7.1 kg liveweight. Replicate 2 was initiated on July 8, 1970 with pigs averaging 47.7 days of age and 10.9 kg liveweight. Within each replicate, 48 pigs of Landrace x Yorkshire (LY) or Hampshire x Yorkshire (HY) breeding were allotted on the basis of sex, weight and breed to the six treatments (Table 1). During the starter (first 6 weeks after allotment) two pigs of one breed and sex were allotted per pen.

¹ Fredeen, H.T., personal communication

During the grower (6 - 12 week) and finisher (12th week - market); however, breeds were no longer separated as there were 4 pigs per pen. Feed intake and gain were recorded as in Experiment I. Pigs were slaughtered at 86 kg (190 lb) liveweight. In each pen, the last pig, regardless of weight, was slaughtered when the third pig reached slaughter weight. As in Experiment I, standard Carcass Valuation (grade index) and R.O.P. Indexes were determined.

2. Metabolism Trials

Metabolism studies were initiated as a part of Experiment II to determine the effects of differing protein levels on N-retention and efficiency of energy utilization.

Twenty-four pigs were selected on the basis of weight on June 18, 1970. Since there were 6 treatments in Experiment II, there were 4 pigs per treatment - two barrows and two gilts; each of these sexes being further divided into LY and HY offspring. As eight metabolism cages were available, three trials of 8 pigs each were conducted on the following dates:

June 26 - July 2, 1970
July 3 - July 9, 1970
July 10 - July 16, 1970

Selection and allotment of pigs was such that average weights were similar; that is, the heavier pigs were used in the first trial, with the lighter pigs being used in subsequent trials. The pigs used had an average age of from 6 to 7 weeks and weighed 10 to 12 kg.

During each trial, the selected pigs were placed in the metabolism cages for three days so they could become accustomed to the cages by the time the trial started. No collections were made during this period. On the morning of the fourth day, the pigs were removed from the cages and weighed. The cages were completely cleaned with water. Total fecal and urinary collections were made for the following three days;

after which time the pigs were removed, weighed again, and placed back in their respective pens.

During each metabolism trial, records and collection procedures were as follows:

i. Feed

Pigs were fed their respective diets during the adjustment and collection periods. In the first two trials, pigs were fed at a level of 90 % of the average daily feed consumed by each pig in the week prior to the metabolism trial. Not all feed was consumed by all pigs in these trials. Therefore, in the third trial, pigs were fed at a level of 80 % of the individual average daily feed consumed in the week prior to the trial. This appeared to be a more satisfactory level of feed allowance.

Pigs in metabolism cages were fed three times daily: at 7:30 a.m.; at 12:00 noon; and at 5:00 p.m. Any feed not consumed during the collection period was collected, dried at 60°C for 72 hours in a forced air oven¹, and left at room temperature for 24 hours to arrive at an 'air dry' basis. It was then weighed and this value was considered as the weigh-back representing feed not consumed. Feed was analyzed separately for each trial (see section on "Methods of Chemical Analysis").

ii. Feces

Feces were collected each morning during the metabolism periods. Each day's collection was placed in a labelled plastic bag and stored at 3°C. After final collection, total feces collections from each pig were thoroughly mixed, total weight was taken, and two samples were withdrawn:

1. Approximately 50 g was taken for gross N analysis. This sample was kept in a labelled plastic bag as before. All N determinations were

¹ Despatch Oven Co., Minneapolis, Minn., U.S.A.

done on duplicate 2.0 g moist feces samples.

2. Another sample, of approximately 200 g, was placed in an aluminum tray for air - dry matter determination. Wet weight was determined and the sample then placed in a forced air oven¹ at 60°C for 72 hr, removed, and allowed to equilibrate to an 'air - dry' basis for a 24 hr period and again weighed for determination of air - dry weight. These samples were then ground through a Size 8 C and N Laboratory Mill² with a 2 mm mesh screen, and placed in a labelled plastic bag, sealed, and gross energy was determined after determination of oven - dry weight. Oven - dry weight was determined on duplicate 2.0 g samples of each feces sample by drying for 24 hr in a forced air oven¹.

iii. Urine

Collections of urine were made at the same time the feces were collected. Volume was measured and recorded at the time of collection. Aliquots of urine were placed in jars, sealed and stored at 3°C such that a total volume of approximately 250 ml was collected over the three day period. N content was determined in duplicate on 5 ml samples of wet urine. Before gross energy determinations were made, approximately 200 ml was placed on a freeze - drier³ for 48 hr, along with a 5 ml urine sample in a tear bulb to determine dry matter content. Duplicate gross energy determinations were made on 1 g samples of freeze - dried urine.

C. Experiment III

1. Growth Studies and Carcass Evaluation

This experiment was carried out at O.A.V.C., Olds, Alberta. Dietary

¹ Despatch Oven Co., Minneapolis, Minn., U.S.A.

² Christy and Norris Ltd., Chelmsford, England.

³ Thermovac Model FD-64 Freeze Dryer, Thermovac Industries Corp., N.Y., U.S.A.

formulations were as used in Experiment II except for the omission of treatment 6 (13 % protein + lysine). Experiment III consisted of two replicates, each replicate being started on December 8, 1969. A total of 90 pigs, averaging 44.9 days of age of mixed breeding (Landrace x Yorkshire, Hampshire x Yorkshire, or Yorkshire x Yorkshire) were allotted on the basis of weight into 10 pens, each pen consisting of 9 pigs, with unequal numbers of each sex per pen. Pigs were fed their respective starters (Table 2) to an overall average age of approximately 77 days, at which time they were changed to their respective growers (Table 2). They were changed to their respective finishing diets (Table 2) at an overall age of approximately 119 days (Table 2), which they were fed until slaughter. Feed intake and rate of gain records were kept throughout and pigs were slaughtered when they reached approximately 90 kg (198 lb) liveweight. Standard Carcass Valuation (Canada Department of Agriculture, 1968) was determined at slaughter.

Methods of Chemical Analysis

Gross feed, fecal and urinary energies were determined using a Parr Oxygen Bomb Calorimeter¹. Values were corrected to an oven - dry basis. Gross N values for feed, feces and urine were done by the Kjeldahl method (AOAC, 1965). The catalyst used in the digestion of all samples was a commercial Kel - Pak². Collection of distilled ammonia was into 50 ml of 4 % boric acid. Protein was determined from N values by multiplying by a factor of 6.25. Tolerances of ± 0.2 percentage units were allowed on duplicate determinations of protein content of each sample. Tolerances of ± 50 calories/g were allowed on

¹ Parr Instrument Company, Moline, Ill., U.S.A.

² Supplies HgO, K₂SO₄ and CuSO₄. Matheson Scientific, East Rutherford, N.J., U.S.A.

duplicate gross energy determinations. Tolerances of ± 0.1 % were allowed on oven - dry matter determinations.

Methods of Statistical Analysis

All data were analyzed on Fortran IV using an analysis of variance program developed by the Department of Computing Science (Easton, 1968). Expected mean squares and valid error term were calculated by a method proposed by Hicks (1964a); the error term was further adjusted (Hicks, 1964b) to make a more accurate and reasonable test. Levels of statistical significance were set at the 5 % level (statistically significant) and at the 1 % level (highly statistically significant). Although significance at the 10 % level is not usually considered as being entirely valid in biological data, it does indicate trends, so was also determined. Significant differences between treatments (multiple means) were further analyzed by application of Duncan's New Multiple Range Test (Steel and Torrie, 1960).

In Experiments I and II, feed and gain data were analyzed on a group mean basis in metric units. Analysis of variance was also done on feed and gain data on the basis of Experiments I and II combined, with the removal of treatments which were not present in both experiments. Feed and gain data were analyzed in British units in Experiment III and later converted to metric units by reference to Units of Weight and Measure, National Bureau of Standards (1960). Conversion factors used were as illustrated in Table 5.

Carcass data on all experiments (I, II, I and II combined, and III) were analyzed in British units and means were then changed to metric units as in Table 5.

Table 5. Conversion factors used in conversion of British units to metric units on feed, gain and carcass data

From:	To:	Multiply by:
in	cm	2.54
sq in	sq cm	6.45
lb	kg	0.454
sq in/lb	sq cm/kg	14.22

Carcass data were analyzed on an individual basis for Experiment I, Experiment II and Experiments I and II combined (with removal of treatments which differed between the two experiments). Carcass data in Experiment III were analyzed on a group mean basis as there were unequal numbers per cell.

In all experiments, missing data were replaced by the mean of that group with the consequent loss of 1 degree of freedom (df) in the error term per replacement (Steel and Torrie, 1960). In analysis of variance of the carcass data, this resulted in the loss of 3 df in the error term for Experiment I, the loss of 1 df in the error term for Experiment II, and the loss of 3 df in the error term when analysis of variance was performed on Experiments I and II combined.

Separate analysis of variance was done on an individual pig basis for the metabolism trials in Experiment II.

RESULTS AND DISCUSSION

Introduction

Presentation and discussion of results are under two major divisions: feeding effects and carcass effects. A third area, the results of protein and energy metabolism, is discussed following this. Within each major division, the results of each experiment are presented, followed by a discussion of the overall effects.

In all tables a code as presented in Table 6 was used in distinguishing levels of significance and differences between factor means.

Table 6. Symbols¹ used in levels of significance between and among means

Symbol used:	Meaning:
o	Following means are significantly different at ($P < .10$)
*	Following means are significantly different at ($P < .05$)
**	Following means are significantly different at ($P < .01$)
a,b,c,d	Means with identical superscripts are not significantly different at levels specified by * or **

¹ Refers to factors within columns.

Feeding Effects

Experiment I

The tabulated results of average daily feed, average daily gain, and feed conversion in Experiment I are presented in Tables 7, 8 and 9 respectively.

Reduced levels of dietary protein caused a reduction ($P < .01$) in feed intake in the starting and growing periods. Protein level had no significant effect in the finishing period, but was significant ($P < .05$) in the overall consideration. This reduced feed intake affected average

Table 7. Experiment I - Means for average daily feed

Factor	Average Daily Feed (kg/day)			
	Starter	Grower	Finisher	Overall
<u>Treatment</u>				
	**	**		*
1	1.20 ^a	2.62 ^a	3.50	2.34 ^a
2	1.20 ^a	2.50 ^{ab}	3.48	2.31 ^a
3	1.13 ^a	2.33 ^b	3.54	2.25 ^a
4	.91 ^b	1.72 ^c	3.24	2.03 ^b
5	.96 ^b	1.72 ^c	3.11	2.03 ^b
<u>Replicate</u>				
		0		0
1	1.11	2.28	3.46	2.26
2	1.05	2.07	3.29	2.12
<u>Sex</u>				
	**			
M	1.02	2.16	3.47	2.19
F	1.15	2.19	3.27	2.19
<u>Overall</u>	1.08	2.17	3.37	2.19

Table 8. Experiment I - Means for average daily gain

Factor	Average Daily Gain (kg/day)			
	Starter	Grower	Finisher	Overall
<u>Treatment</u>				
	**	**		**
1	.54 ^a	.77 ^a	.80	.70 ^a
2	.53 ^a	.71 ^a	.90	.70 ^a
3	.45 ^b	.78 ^a	.87	.69 ^a
4	.29 ^c	.52 ^b	.89	.59 ^b
5	.31 ^c	.51 ^b	.87	.57 ^b
<u>Replicate</u>				
1	.44	.66	.86	.66
2	.41	.65	.88	.64
<u>Sex</u>				
	*			
M	.39	.66	.88	.64
F	.45	.66	.85	.65
<u>Overall</u>	.42	.66	.87	.65

Table 9. Experiment I - Means for efficiency of feed conversion

Factor	Feed Conversion (kg feed/kg gain)			
	Starter	Grower	Finisher	Overall
<u>Treatment</u>				
	0	**	**	0
1	2.23	3.41 ^a	4.48 ^a	3.39
2	2.53	3.53 ^a	3.88 ^{bc}	3.28
3	2.51	2.98 ^b	4.09 ^b	3.26
4	3.24	3.29 ^a	3.62 ^{dc}	3.46
5	3.18	3.40 ^a	3.57 ^d	3.45
<u>Replicate</u>				
		**	*	*
1	2.74	3.45	4.07	3.43
2	2.74	3.19	3.79	3.31
<u>Sex</u>				
				0
M	2.76	3.29	3.98	3.41
F	2.72	3.35	3.88	3.32
<u>Overall</u>	2.74	3.32	3.93	3.37

daily gain where there was a depression ($P < .01$) in gain in the starting and growing periods and in the overall experiment, but not in the finishing period. Feed conversion, however, was affected ($P < .01$) in the growing and finishing periods only, indicating a compensatory growth effect; with feed conversion being most efficient in treatment 3 in the growing period, and most efficient in treatments 4 and 5 in the finishing period. Supplementation of the low protein diet with lysine and methionine (treatment 5) in the starter did not improve feed intake, gain or feed conversion in any period above that of the low protein diet (treatment 4).

Gilts ate a greater amount ($P < .01$) than barrows during the starting period with faster ($P < .01$) gain but no significant difference in feed conversion. Barrows compensated by higher feed intake and gain during the finishing period but there was no difference in conversion. Gilts

tended to be better in overall feed conversion but this was significant at $P < .10$ only.

Experiment II

Results of average daily feed consumption, average daily gain and feed conversion in Experiment II are given through tables 10 to 12 inclusive. Feed consumption was reduced ($P < .05$) with reduced dietary protein levels during the growing, finishing and overall periods, with no effect being observed during the starting period. Intake was improved in all periods on diets supplemented with amino acids relative to the low protein diet (treatment 4). Average daily gain was reduced ($P < .01$) with reduced dietary protein level in the starting, and growing periods and the overall experiment. Gain was improved with amino acid supplementation of the low protein diet. Feed conversion was affected ($P < .01$) by dietary protein level and balance in all growth periods and overall, with a compensatory effect being observed on low protein diets during the growing and finishing periods.

The effect of amino acid supplementation on low protein diets appears to be one of improved feed intake, improved gain and improved feed conversion. Feed intake was improved more on lysine plus methionine supplemented diets than on just lysine supplemented diets but feed conversion was better overall on lysine supplemented diets.

The performance of gilts and barrows varied between growth periods in Experiment II. Feed intake and gain were similar in the starting period but gilts had lower ($P < .01$) feed intake and gain during the growing, finishing and overall periods and had an overall better ($P < .05$) feed conversion.

The only significant breed difference exhibited was in the starting

Table 10. Experiment II - Means for average daily feed

Factor	Average Daily Feed (kg/day)			Overall
	Starter	Grower	Finisher	
<u>Treatment</u>				
		*	*	*
1	1.21	2.64 ^a	3.42 ^a	2.19 ^a
2	1.23	2.43 ^b	3.24 ^c	2.18 ^a
3	1.22	2.31 ^{bc}	3.37 ^{ab}	2.12 ^b
4	1.13	1.96 ^d	2.94 ^d	2.02 ^d
5	1.21	2.33 ^b	3.20 ^c	2.09 ^{bc}
6	1.15	2.16 ^{dc}	3.28 ^{bc}	2.07 ^c
<u>Replicate</u>				
	**	**	*	**
1	1.02	2.15	3.33	2.06
2	1.37	2.46	3.16	2.16
<u>Sex</u>				
		**	**	**
M	1.19	2.48	3.44	2.19
F	1.19	2.12	3.04	2.03
<u>Breed</u>				
LY	1.21	---	---	---
HY	1.18	---	---	---
<u>Overall</u>	1.19	2.30	3.24	2.11

period and was related to liveweight gain. Here, LY pigs gained faster ($P < .05$) than HY pigs.

Differences in feed intake and gain between replicates may be explained by differences in starting ages between pigs in each replicate.

Experiments I and II Combined

Tables 13, 14 and 15 contain results of feed intake, gain and feed conversion respectively for Experiments I and II combined. Combining the results allows the separation of possible effects associated with replicates over a prolonged time period. Feed intake was reduced ($P < .01$) on low dietary protein sequence diets (treatment 4) in starting,

Table 11. Experiment II - Means for average daily gain

Factor	Average Daily Gain (kg/day)			Overall
	Starter	Grower	Finisher	
<u>Treatment</u>	**	**	o	**
1	.55 ^a	.74 ^{ab}	.87	.70 ^a
2	.54 ^a	.70 ^b	.92	.69 ^a
3	.47 ^b	.77 ^a	.95	.70 ^a
4	.32 ^d	.56 ^c	.84	.57 ^b
5	.41 ^c	.72 ^b	.92	.65 ^a
6	.39 ^c	.73 ^{ab}	.97	.67 ^a
<u>Replicate</u>	**	o	*	**
1	.37	.69	.95	.65
2	.53	.72	.88	.68
<u>Sex</u>		**	**	**
M	.44	.73	.96	.68
F	.46	.67	.86	.65
<u>Breed</u>	*			
LY	.46	---	---	---
HY	.43	---	---	---
<u>Overall</u>	.45	.70	.91	.66

growing and overall periods. Feed intake was still reduced ($P < .05$) during the finishing period in treatment 4. Supplements of amino acids to the low protein diet during the starting period had no significant effect on feed intake. Associated with a reduced feed intake on low protein sequence diets was a depression ($P < .01$) in average daily gain in the starting, growing and overall periods. Gain was also depressed ($P < .05$) in the finishing period. There was less effect on gain as the pigs aged, indicating a compensatory growth response as dietary protein became less critical for normal growth. In the starting period, addition

Table 12. Experiment II - Means for efficiency of feed conversion

Factor	Feed Conversion (kg feed/kg gain)			
	Starter	Grower	Finisher	Overall
<u>Treatment</u>				
	**	**	**	**
1	2.19 ^c	3.30 ^b	3.95 ^a	3.09 ^{cd}
2	2.28 ^c	3.48 ^a	3.53 ^b	3.15 ^{bc}
3	2.71 ^b	2.98 ^c	3.57 ^b	3.04 ^d
4	3.57 ^a	3.56 ^a	3.50 ^{bc}	3.52 ^a
5	2.98 ^b	3.01 ^c	3.38 ^c	3.20 ^b
6	2.99 ^b	2.96 ^c	3.36 ^c	3.10 ^{cd}
<u>Replicate</u>				
1	2.86	3.16	3.51	3.20
2	2.71	3.26	3.58	3.17
<u>Sex</u>				
				*
M	2.77	3.24	3.55	3.23
F	2.80	3.19	3.54	3.13
<u>Breed</u>				
L				
LY	2.73	---	---	---
HY	2.84	---	---	---
<u>Overall</u>	2.79	3.21	3.55	3.18

of lysine and methionine improved gain to a level above that of pigs fed the low protein diet but less than that of pigs fed higher levels of protein.

Feed conversion efficiency was depressed ($P < .01$) in the starting period on pigs fed low levels of protein, but was improved with the addition of lysine and methionine to the low protein diet. Feed conversion improved on low protein diets relative to the higher protein diets with increased age of the pigs, and in the finishing period, feed conversion was best on the lowest sequence of dietary protein fed. This again illustrated

Table 13. Experiments I and II combined - Means for average daily feed

Factor	Average Daily Feed (kg/day)			
	Starter	Grower	Finisher	Overall
<u>Treatment</u>				
	**	**	*	**
1	1.21 ^a	2.63 ^a	3.46 ^a	2.26 ^a
2	1.22 ^a	2.46 ^b	3.36 ^a	2.24 ^a
3	1.17 ^{ab}	2.32 ^c	3.45 ^a	2.19 ^a
4	1.02 ^c	1.84 ^d	3.09 ^b	2.02 ^b
5	1.09 ^{bc}	---	---	---
<u>Experiment</u>				
I	1.08	2.29	3.44	2.23
II	1.20	2.33	3.24	2.13
<u>Replicate</u>				
	**		*	*
1	1.07	2.31	3.44	2.20
2	1.21	2.31	3.24	2.16
<u>Sex</u>				
	*	*	**	
M	1.11	2.39	3.48	2.21
F	1.17	2.23	3.20	2.14
<u>Overall</u>	1.14	2.31	3.34	2.18

a compensatory growth response with increased age.

Although barrows ate less ($P<.05$) in the starting period, they ate more ($P<.05$) in the growing period and more ($P<.01$) in the finishing period. For the entire experiment, there was no overall difference in feed intake between the sexes. Barrows gained slower ($P<.01$) in the starting period, but faster ($P<.01$) in the finishing period; there being no significant differences in the growing and overall periods. Gilts were more efficient ($P<.01$) in feed conversion when considered through all growth periods, but exhibited no significant difference within each growth period.

Table 14. Experiments I and II combined - Means for average daily gain

Factor	Average Daily Gain (kg/day)			
	Starter	Grower	Finisher	Overall
<u>Treatment</u>				
	**	**	*	**
1	.54 ^a	.76 ^a	.83 ^b	.70 ^a
2	.54 ^a	.70 ^b	.91 ^a	.70 ^a
3	.46 ^b	.78 ^a	.91 ^a	.70 ^a
4	.31 ^c	.54 ^c	.87 ^c	.58 ^b
5	.36 ^d	---	---	---
<u>Experiment</u>				
I	.42	.69	.86	.67
II	.46	.69	.89	.67
<u>Replicate</u>				
	**		*	o
1	.41	.69	.89	.66
2	.47	.69	.87	.67
<u>Sex</u>				
	**		**	
M	.42	.71	.91	.67
F	.46	.68	.85	.67
<u>Overall</u>	.44	.69	.88	.67

A highly significant ($P < .01$) treatment x sex interaction was observed on overall feed conversion (Appendix A). Gilts were more efficient converters of high protein diets than barrows with less effect as dietary protein levels decreased. A significant ($P < .05$) treatment x sex interaction was also noted in feed intake during the growing period. Here, feed intake was consistently higher for barrows than gilts except in the lowest protein diet (treatment 4), in which gilts ate more than barrows. Highly significant ($P < .01$) interactions between sex x experiment were observed between feed intake during the starting and growing periods, and liveweight gain during the finishing and overall periods. Although

Table 15. Experiments I and II combined - Means for efficiency of feed conversion

Factor	Feed Conversion (kg feed/kg gain)			
	Starter	Grower	Finisher	Overall
<u>Treatment</u>				
	**	**	**	**
1	2.21 ^a	3.35 ^c	4.21 ^a	3.24 ^b
2	2.40 ^a	3.51 ^a	3.70 ^b	3.21 ^c
3	2.61 ^a	2.98 ^d	3.83 ^b	3.15 ^d
4	3.41 ^c	3.42 ^b	3.56 ^c	3.49 ^a
5	3.08 ^b	---	---	---
<u>Experiment</u>				
I	2.74	3.30	4.02	3.35
II	2.75	3.33	3.63	3.20
<u>Replicate</u>				
		**	**	**
1	2.78	3.35	3.88	3.31
2	2.71	3.28	3.77	3.24
<u>Sex</u>				**
M	2.75	3.33	3.86	3.32
F	2.74	3.30	3.79	3.22
<u>Overall</u>	2.74	3.31	3.83	3.27

barrows generally ate less and gained slower than gilts in Experiment I the opposite occurred in Experiment II.

Experiment III

Tabulated results of feed, growth and feed conversion data in Experiment III are presented in Tables 16, 17 and 18. Although variations in feed intake occurred they did not reach significance. Feed intake tended to be reduced with lower levels of dietary protein in the starting period but was less evident in later growth periods. Lysine and methionine supplements tended to improve feed intake, but this was not significant. Average daily gain also tended to be depressed as dietary protein level de-

Table 16. Experiment III - Means for average daily feed

Factor	Average Daily Feed (kg/day)			Overall
	Starter	Grower	Finisher	
<u>Treatment</u>				
1	.79	1.46	2.18	1.75
2	.82	1.61	2.58	2.02
3	.66	1.50	2.75	2.01
4	.56	1.22	2.17	1.67
5	.62	1.43	2.36	1.81
<u>Replicate</u>				
1	.67	1.43	2.31	1.80
2	.70	1.46	2.51	1.90
<u>Overall</u>	.69	1.45	2.41	1.85

Table 17. Experiment III - Means for average daily gain

Factor	Average Daily Gain (kg/day)			Overall
	Starter	Grower	Finisher	
<u>Treatment</u>				
		*		*
1	.42	.57 ^a	.81	.64 ^b
2	.40	.55 ^a	.76	.62 ^b
3	.33	.57 ^a	.81	.66 ^a
4	.23	.33 ^b	.78	.58 ^b
5	.32	.47 ^{ab}	.81	.63 ^b
<u>Replicate</u>				
				^o
1	.34	.47	.77	.61
2	.36	.53	.80	.64
<u>Sex</u>				
			**	**
M	.34	.53	.84	.65
F	.36	.47	.73	.59
<u>Overall</u>	.35	.50	.78	.63

Table 18. Experiment III - Means for efficiency of feed conversion

Factor	Feed Conversion (kg feed/kg gain)			Overall
	Starter	Grower	Finisher	
<u>Treatment</u>				
1	1.87	2.56	3.07	2.93
2	2.11	3.02	3.49	3.29
3	1.94	2.63	3.44	3.08
4	2.02	3.87	2.85	2.94
5	1.82	3.04	2.97	2.89
<u>Replicate</u>				
1	1.96	3.22	3.10	2.98
2	1.93	2.82	3.23	3.07
<u>Overall</u>	1.95	3.02	3.16	3.02

clined in the starting period and was less ($P < .05$) in the growing period. There were no significant effects in the finishing period but significance ($P < .05$) was noted in overall average daily gain between treatments with pigs in treatment 3 gaining fastest. Supplementation of low protein diets with lysine and methionine improved rate of gain equivalent to gain on higher dietary protein levels. No significant differences in feed conversion related to dietary protein level were noted but pigs fed lower levels of protein in earlier periods tended to be more efficient in feed conversion during the finishing period. Again, lysine and methionine supplements had little effect on feed conversion efficiency.

Although gilts gained slightly faster than barrows during the starting period, barrows gained faster than gilts in subsequent periods; with the difference being highly significant ($P < .01$) in the finishing and overall periods.

A significant ($P < .05$) treatment x sex interaction in overall average

daily gain was observed; gilts showed a decline in gain between treatments 1 and 2 with an increase in gain between treatments 2 and 3 but barrows exhibited opposite trends in this comparison. Between treatments 3, 4 and 5 however, barrows and gilts responded in similar fashion.

Overall Discussion

The reduced feed intake generally observed on low protein diets in all experiments could be the result of an inadequate dietary protein level relative to energy level or it could be associated with an amino acid imbalance. The concept of an amino acid imbalance was reviewed by Elvehjem (1956) as were amino acid antagonisms and toxicities. Amino acid imbalances are further discussed by Harper and Kumpta (1959). Harper (1964) defines an amino acid imbalance as "a change in the proportions of amino acids in a diet which results in a depression in food intake or growth rate that can be completely prevented by a supplement of the indispensable amino acid present in least amount required for optimum performance". Smith and Lewis (1966) reduce all interactions between amino acids to antagonisms between pairs of amino acids which are members of small groups among which interaction is possible.

The general improvement in feed intake and gain on the low protein diet (treatment 4) upon supplementation with lysine plus methionine (Experiment I, II, III) or lysine (Experiment II) is consistent with what would be expected on correction of an amino acid imbalance as defined by Harper (1964). However, improved feed intake and gain could also be due to an improvement of the ratio between essential and non-essential amino acids in the diet (Mitchell et al, 1968a) which could be considered as an improvement in amino acid balance but not as defined by Harper (1964).

The general depression in feed intake, average daily gain and feed conversion efficiency on low protein diets (treatment 4) were obvious during the starting period only. In the growing and finishing periods, average daily feed, average daily gain and especially feed conversion efficiency were improved on low protein or amino acid supplemented diets compared with higher protein diets. This effect could be termed one of compensatory growth and has previously been observed (O'Grady and Bowland¹ 1971; Wyllie et al, 1969; Robinson, Morgan and Lewis, 1964a; Bowland and Berg, 1959). As dietary protein became a less limiting factor during later periods of growth, pigs fed low protein levels in earlier periods utilized feed more efficiently for conversion into liveweight gain.

Generally, feed intake was greater in barrows than gilts, as has been observed previously (Skitsko and Bowland, 1970a; Young et al, 1968; Blair and English, 1965). In the present experiments, however, barrows ate more than gilts during growing, finishing and overall periods, but females consumed feed equal to or greater than that consumed by barrows in the starting period. It has been observed previously (Anderson and Bowland, 1967) that sex of pigs has little effect on feed intake or gain in the early starting period.

Carcass Effects

Before discussing the effects of diet, breed and sex on carcass quality, it is necessary to review current methods of measuring and determining carcass quality. In Canada, measurements of carcass quality have been based on the recently revised 'hog carcass valuation system' (Canada Department of Agriculture, 1968); the old ROP Index (Fredeen, 1966), herein called 'OROP'; and the recently revised new ROP Index²,

¹ Unpublished data

² Fredeen, H.T., personal communication

herein called 'NROP'.

One major reason that the new carcass valuation system was initiated was because the old grading system did not closely reflect ranges of differences in individual carcass values between or within grades. This new system was also developed to encourage the producer to produce leaner carcasses (Canada Department of Agriculture, 1968).

The carcass valuation index is determined from total backfat and warm carcass weight. Total backfat is defined as the sum of maximum depth of shoulder fat plus maximum depth of loin fat, measured to the nearest tenth of an inch. Carcass weight is the warm, dressed weight of the hog. These two measurements are applied to what is termed a "Table of Differentials". The first column of this table shows the total of the two backfat measurements and the first row carcass weight. From this table the grade index is determined.

Market bids for hogs are made on a warm, dressed weight basis; the bid price is based on a carcass with an index of "100". Carcasses that have an index of greater than 100 (less backfat relative to warm carcass weight) are worth that fraction more per pound, while those carcasses showing an index of less than 100 are worth that fraction less per pound.

The OROP index is a measurement of carcass quality as determined by:

$$\text{OROP} = 55.26 - 2.115(A) + .937(B) + .124(C) + .604(D) + .456(E) - .063(F)$$

where:

- A = Total Backfat (sum of shoulder, back and loin, in)
- B = Loin Area (Area of loin at 14th rib, sq in)
- C = Lean in Ham Face (%)
- D = Ham/Carcass (%)
- E = Carcass Length (in)
- F = Carcass Weight (lb)

The NROP index is determined by:

$$\text{NROP} = 51.68 - 3.234(G) + 1.0381(H) + .485(I) + 11.766(J) \pm (K)$$

where:

- G = Total Backfat (sum of shoulder, back and loin, in)
- H = Loin Area (Area of Loin at 14th rib, sq in)
- I = Ham/Carcass (%)
- J = Area Lean of Ham/Ham Weight (sq in/lb)
- K = Sex Correction Factor (+1.1 percent for barrows; -1.1 percent for gilts)¹

Experiment I

Factor means of slaughter age and carcass data for Experiment I are presented in Table 19. Slaughter age was not affected by diet in treatments 1, 2 or 3. However, feeding the low protein diet sequence, with or without lysine plus methionine during the starting period caused an increase ($P < .01$) in age at slaughter. No differences in slaughter age were observed between low protein diets or a low protein diet supplemented with lysine and methionine during the starting period (treatments 4 and 5).

Trends ($P < .10$) were noted between treatments on ham/carcass (%); lean in ham face (%) and lean area ham/ham weight. In comparison with treatments 1, 2 and 3, treatments 4 and 5 tended to have less ham/carcass (%) but treatment 5 was superior to treatment 4 in lean in ham face (%) and lean area ham/ham weight.

A significant ($P < .05$) treatment x sex interaction (Appendix A) was noted wherein barrows had increased lean area ham/ham weight with lysine plus methionine supplements but gilts did not.

Gilts had less ($P < .01$) total backfat and tended ($P < .10$) to have larger loin area and greater ham/carcass (%) than barrows. Gilts also had highly significantly ($P < .01$) more lean in ham face (%), longer car-

¹ No sex correction was made in this analysis

casses, higher NROP and OROP ratings and a higher grade index than barrows. This indicated that gilts produced higher quality carcasses than barrows, irrespective of treatment.

No significant differences related to any factor were noted in carcass weight or dressing %.

Experiment II

Tabulated results of Experiment II slaughter age and carcass data are presented in Table 20.

Slaughter age was not affected by diet in treatments 1, 2, 3, 5 or 6. An increase ($P < .01$) in slaughter age occurred in treatment 4. Supplementation of the low protein diet sequence (treatment 4) with methionine and lysine or lysine (treatments 5 and 6 respectively) in all growth periods improved growth rate such that slaughter age was no longer significantly different to pigs fed higher level protein diets.

Loin area was influenced ($P < .01$) by dietary treatment as was carcass length. Feeding the low protein diet (treatment 4) resulted in a reduction in loin area but supplements of lysine and methionine or lysine (treatment 5 and 6 respectively) caused an increase in loin area above that of pigs fed treatments 1, 2 or 3. Carcass length was reduced in treatment 4 and was increased by amino acid supplements.

Trends ($P < .10$) were noted in lean in ham face (%), OROP and grade index between treatments. Supplementation with amino acids generally improved lean in ham face (%), OROP and grade index above that of treatment 4 but not to a level equal to higher levels of protein fed (treatments 1, 2 and 3).

Several highly significant ($P < .01$) differences were noted between sexes. Barrows had more total backfat, less loin area, less ham/carcass

(%), less lean in ham face (%), lower OROP and NROP ratings, and also shorter ($P < .05$) carcasses and less days of age at slaughter than gilts. Barrows also tended ($P < .10$) to be lower in dressing % than gilts.

Differences between breeds were also noted. LY pigs had highly significantly ($P < .01$) more total backfat and shorter carcasses and lower ($P < .05$) grade indexes than HY pigs; but HY pigs had less ($P < .05$) ham/carcass (%) and tended ($P < .10$) to be lower in dressing % than LY pigs.

Significant ($P < .05$) breed x treatment interactions were noted (Appendix A) in total backfat, loin area, carcass length, NROP and OROP. Total backfat was more reduced on low protein diets in HY than LY pigs. HY pigs were more responsive to amino acid supplementation in loin area than LY pigs. HY pigs generally had longer carcasses than LY pigs but the reverse was true on low protein diets. However, HY pigs had higher ROP ratings than did the LY pigs on low protein or amino acid supplemented diets. A highly significant ($P < .01$) breed x treatment interaction (Appendix A) was noted on carcass weight. Carcass weight was less in HY than LY pigs fed low protein diets. Also, a significant ($P < .05$) treatment x sex interaction (Appendix A) was noted in Experiment II. Although lean area ham/ham weight was not affected by sex or treatment alone, barrows showed more response to amino acid supplements than did gilts.

Experiments I and II Combined

Experiments I and II combined are considered in Table 21 which gives the factor means contributing to measurements of carcass quality. Factor means of slaughter age are also given.

Feeding a low protein diet (treatment 4) caused an increase ($P < .01$) in slaughter age in comparison with pigs fed the other diets. Dietary

treatment had an effect ($P < .01$) on loin area, with treatment 3 producing the largest loin area in pigs, followed by treatments 2, 1 and 4 respectively. Lean in ham face (%) was reduced ($P < .05$) by low dietary protein sequence feeding as was grade index. OROP tended ($P < .10$) to be reduced on the lowest protein level sequence fed (treatment 4).

Several highly significant ($P < .01$) effects were noted between sexes. Gilts had less total backfat, larger loin area, more ham/carcass (%), more lean in ham face (%), longer carcasses and higher NROP and OROP ratings than barrows. Gilts also had a better ($P < .05$) grade index but were older ($P < .05$) at slaughter than barrows.

A significant ($P < .05$) treatment x sex interaction (Appendix A) was noted in lean in ham face (%). Although gilts had consistently more lean in ham face (%) than barrows and a general decline in lean in ham face (%) was observed as dietary protein level fell; barrows exhibited an improvement from treatment 1 to 2; gilts exhibited the reverse. From treatment 2 to treatment 3, barrows showed a reduction in lean in ham face (%) whereas gilts had an increase. Both barrows and gilts exhibited a reduced lean in ham face (%) in treatment 4, with barrows being more affected.

In many of these complex interactions, no specific interpretations can be made and no definite reason advanced for the interactive effects.

Experiment III

In Experiment III, carcass data and slaughter age (Table 22) were not affected by treatment but barrows had more ($P < .01$) total backfat and higher ($P < .05$) dressing %, lower grade index and reduced age at slaughter in comparison with gilts. There was a tendency ($P < .10$) for barrows

Table 22. Experiment III - Means for slaughter age and carcass data

Factor	Slaughter age days	Carcass weight kg	Dressing %	Total backfat ¹ cm	Grade index
<u>Treatment</u>					
1	175	70.7	77.7	8.2	100.3
2	179	70.5	77.5	7.9	101.1
3	169	71.6	78.4	8.1	101.4
4	186	70.6	77.7	8.0	101.4
5	176	71.4	78.5	8.3	100.5
<u>Replicate</u>					
1	180	70.7	77.7	8.0	101.3
2	174	71.2	78.3	8.2	100.5
<u>Sex</u>					
	*	o	*	**	*
M	172	71.6	78.5	8.6	99.3
F	182	70.3	77.4	7.6	102.4
<u>Overall</u>	177	71.0	78.0	8.1	100.9
¹ Sum of shoulder and loin fat					

to have heavier carcasses and this difference might have had a minor influence on comparisons between gilt and barrow carcasses.

No interactions between treatment, replicate, or sex on carcass data were noted.

Overall Discussion

Feeding a low protein diet throughout (treatment 4) had a highly significant ($P < .01$) effect on slaughter age except in Experiment III where no differences were noted. This general increase in slaughter age was due to an overall reduction in average daily gain in pigs fed low protein diets similar to that observed previously (Davey and Morgan, 1969;

Young et al, 1968; Seymour et al, 1964). An increase in slaughter age on low protein diets was also reported by Clawson (1967). A reduced slaughter age with amino acid supplements due to increased average daily gain was obtained in the present experiment and has also been observed with lysine supplementation (Dent et al, 1970; Wahlstrom, Taylor and Seerley, 1970; Nielson et al, 1963) and simultaneous lysine and methionine supplementation (Bayley and Summers, 1968; Meade et al, 1965).

No treatment effects on total backfat were observed in any experiment. This lack of influence of protein level on backfat thickness is in agreement with Jurgens et al (1967) and Clawson et al (1962). The observation that supplements of lysine have no effect on backfat thickness has also been noted (Meade, Dukelow and Grant, 1966; Reimer, Meade and Grant, 1964) as has lack of effect from simultaneous lysine and methionine addition (Meade, Dukelow and Grant, 1966; Reimer, Meade and Grant, 1964).

Although treatment had no significant effect on loin area in Experiment I, highly significant differences were observed in Experiment II. A reduction in loin area on pigs fed low protein diets is consistent with observations of Bell and Voldeng (1968), Hale and Southwell (1967), and Seerley, Poley and Wahlstrom (1964). Supplemental amino acids increased loin area above that of diets not supplemented, in agreement with reports by Cahilly et al (1963), Vipperman et al (1963) and Clawson, Barrick and Smart (1963); but contrary to Meade, Dukelow and Grant (1966) and Reimer, Meade and Grant (1964).

Treatment generally had no effect on dressing percentage, in agreement with Meade et al (1969a, 1969b) and Jurgens et al (1967) but contrary to Wagner et al (1963). As discussed in the literature review, the variability of results in previously reported studies can generally be re-

conciled on the basis of protein and amino acid levels in the diets being compared.

Several differences between sexes in carcass measurements irrespective of treatment were observed. Gilts had consistently less total backfat than barrows, in agreement with Friend and MacIntyre (1970), Skitsko and Bowland (1970a), Wagner et al (1963) and Bowland and Berg (1959). Gilts also had more loin area than barrows which has been observed previously by Skitsko and Bowland (1970a), Bruner and Swiger (1968), Bell (1965) and Robinson, Morgan and Lewis (1964b). Gilts also tended to have greater carcass length than barrows, as reported previously by Hale and Southwell (1967), Bell (1965), Robinson, Morgan and Lewis (1964b) and Bowland and Berg (1959). Gilts have previously been shown to have greater ham/carcass (%) (Skitsko and Bowland, 1970; Young et al, 1968). A generally greater ham of carcass (%) by gilts may be considered as overall criteria for leaner carcasses for gilts than barrows which agrees with most other observations (Cahilly et al, 1963; Wagner et al, 1963; Bowland and Berg, 1959). Differences between sexes in ROP ratings and grade index with gilts being superior may be considered as indicative of the ability of gilts to produce superior carcasses compared with barrows. However, using the 'sex correction factor' in NROP removed the differences between sexes as reported in this study.

Results of the carcass evaluation in Experiment II would indicate that HY pigs were the superior breed in carcass quality. HY pigs had less total backfat, longer carcasses and a better grade index than LY pigs, and tended to reach slaughter at an earlier age.

Metabolism Trials

Means of protein digestibility and N-retention, and DE and ME are

presented in Tables 23 and 24 respectively.

There were no differences in feed intake during the metabolism periods. There were differences ($P < .05$) in N digested (g) with pigs fed higher levels of protein digesting more N on a daily basis, as would be expected. Protein digestibility (%) was not affected by dietary protein level or balance but tended to be higher on higher levels of dietary protein. N-retention of gross N (%) was not significantly affected at any level, but g N retained as a percentage of gross N tended to be more on low protein diets. N-retention of digestible N (DN) (%) tended to be higher on lower protein diets, but again, none of these values were significantly different at any level.

No significant differences were noted between breed or sex in relation to any measurements of protein digestibility or N-retention. Significant ($P < .05$) interactions were noted in daily feed and N-retention of DN (%) between breed and sex. LY barrows ate less and retained less N of DN (%) than HY barrows, but HY gilts ate less and retained less N of DN (%) than LY gilts.

A tendency for protein digestibility (%) to be higher at higher dietary protein levels would be in agreement with McConnell, Barth and Griffin (1971), Standish and Bowland (1967), and Greeley et al (1964). A tendency for N-retention (%) to be improved as dietary protein level was decreased is in agreement with Rutledge, Hanson and Meade (1961). However, in the present study, none of these trends were significant at any level, consequently, any conclusions drawn would be speculative only.

Significant ($P < .05$) differences were noted in DE/kg feed, ME/kg feed, ME as % of DE and calculated ME, which were not related to dietary protein level or balance. These values could probably be related to gross energy

Table 23. Experiment II - Means for protein digestibility and N-retention¹

Factor	Daily feed (g)	N digested (g)	Protein digestibility (%)	N-retention of gross N (g)	N-retention of gross N (%)	N-retention of digestible N (%)
<u>Treatment</u>						
1	601	* 18.6 ^a	80.8	11.4	48.8	60.5
2	623	18.0 ^a	74.4	11.2	44.6	58.5
3	604	13.8 ^{ab}	80.6	9.1	53.3	66.4
4	561	11.1 ^b	78.8	8.0	56.8	71.4
5	602	10.9 ^b	75.3	7.5	51.2	68.3
6	602	10.9 ^b	75.6	7.1	49.0	64.7
<u>Sex</u>						
M	582	13.9	78.9	8.8	50.6	63.9
F	616	13.9	76.2	9.3	50.6	66.0
<u>Breed</u>						
LY	617	14.0	75.7	8.8	47.1	62.4
HY	581	13.8	79.5	9.3	54.1	67.5
<u>Overall</u>	599	13.9	77.6	9.0	50.6	65.0
<u>1 100 % dry-matter basis</u>						

Table 24. Experiment II - Means for digestible and metabolizable energy¹

Factor	DE/kg feed	% digestibility	ME/kg feed	ME as % of DE	Calculated ME ²
<u>Treatment</u>					
1	* 3157 ^{bc}	80.0	* 3093 ^{bc}	* 97.7 ^{bc}	* 3029 ^{bc}
2	3019 ^c	76.5	2947 ^c	97.6 ^c	2897 ^c
3	3751 ^a	85.7	3682 ^a	98.1 ^a	3600 ^a
4	3447 ^{ab}	83.6	3396 ^{ab}	98.6 ^{bc}	3308 ^{ab}
5	3216 ^{bc}	78.6	3150 ^{bc}	98.0 ^b	3086 ^{bc}
6	3373 ^{abc}	81.3	3308 ^{abc}	98.1 ^b	3237 ^{abc}
<u>Sex</u>					
M	3365	81.9	3306	* 98.2	3229
F	3289	80.0	3220	97.8	3156
<u>Breed</u>					
LY	3281	79.9	3220	98.1	3148
HY	3373	82.1	3305	97.8	3237
<u>Overall</u>	3327	81.0	3263	98.0	3193
1	100 % dry-matter basis				
2	ME (kcal/kg) for swine = DE (kcal/kg) × $\left[\frac{96 - (0.202 \times \text{protein \%})}{100} \right]$				

values of the feed and not directly due to differences between treatments. However, this does not explain significant ($P < .05$) differences between treatment on ME as % of DE where no definite trends related to treatment could be established. Significant ($P < .05$) differences between sex were noted in ME as % of DE with barrows having higher values as did LY pigs over HY pigs at the ($P < .10$) level. No other differences between breed or sex were noted.

A significant ($P < .05$) breed x sex interaction was observed in ME as % of DE. LY barrows had higher values than HY barrows but HY gilts had higher values than LY females. A significant ($P < .05$) breed x treatment interaction was also noted on ME as % of DE. HY pigs generally had lower ME as % of DE values in treatments 1 and 2 and higher values in treatments 3 and 4 but showed less response to amino acid supplementation (treatments 5 and 6) than LY pigs. In many of these complex interactions no specific interpretation can be made and no definite reason advanced for the interactive effects.

GENERAL SUMMARY AND DISCUSSION

Dietary protein level and balance generally had an influence on feed intake, with pigs fed the lowest sequence of dietary protein exhibiting a reduced feed intake. Supplements of amino acids in an effort to improve amino acid balance generally resulted in an improved feed intake. Response usually was not as good when low protein diets were supplemented with lysine as when they were supplemented with lysine and methionine simultaneously. Feed intake was affected less by dietary protein level and balance in later periods of growth than it was in the starting period.

Associated with a reduced feed intake which occurred on low levels of dietary protein, average daily gain and feed conversion efficiency were affected, especially in the early stages of growth. Average daily gain was lower and feed conversion poorer on the low protein diet fed to pigs in the starting period. Supplementation of this low protein diet with methionine and lysine or lysine generally improved average daily gain and feed conversion efficiency but not to a level equivalent to that of pigs fed higher levels of dietary protein. In the growing and finishing periods, however, pigs fed low levels of dietary protein in the starting period generally gained faster and were more efficient in feed conversion frequently being superior in performance to those receiving higher dietary protein levels. This phenomenon could be termed one of compensatory growth in which, as protein level or balance became a less important factor in feed intake and/or gain, pigs fed low levels of dietary protein throughout utilized feed more efficiently and gained equal to or faster than pigs fed higher levels of dietary protein in earlier periods of growth. This effect was less marked on pigs fed diets supple-

mented with methionine and lysine as those pigs were more efficient throughout. Generally, supplementation with lysine alone improved average daily gain and feed conversion to a level equal or greater than diets supplemented simultaneously with lysine and methionine.

Dietary treatment affected slaughter age and several measurements of carcass quality. Slaughter age was generally increased as dietary protein level fell, with pigs fed the lowest protein sequence being generally retarded in growth rate and hence slaughter age. Supplementation of this diet with methionine and lysine or lysine throughout had variable effects as it reduced slaughter age in Experiment II, but had no effect in Experiment III.

Treatment had little influence on dressing %, total backfat, ham/carcass (%) or ROP ratings. Loin area was reduced on the low protein diets, as was lean in ham face (%), carcass length and grade index, but was improved with methionine and lysine or lysine supplements. Lean area ham/ham weight was also generally improved with amino acid supplementation of the diets. Supplementation with lysine was generally as beneficial in improving carcass quality as simultaneous addition of lysine and methionine.

The digestibility and retention data gave little information that could be related directly to performance or carcass quality except that protein digested and retained on a daily basis was higher for high protein diets than for low protein diets.

Barrows ate more during the overall experiments and in the growing and finishing periods than did gilts, but gilts ate as much or more than barrows in the starting period. Barrows gained faster than gilts except in the earlier periods of growth.

Several carcass differences were observed between sexes irrespective

of treatment. Gilts had consistently less total backfat, greater loin area and superior ROP ratings and grade indexes, although they tended to reach slaughter weight later than barrows. Gilts also tended to have greater ham/carcass (%), lean in ham face (%) and lean area ham/ham weight and longer carcasses than barrows; all of which measures are suggestive of increased lean compared with fat in the carcasses.

No conclusive differences were observed between breeds in performance insofar as feed intake, gain and feed conversion were concerned. HY pigs tended to produce higher quality carcasses than LY pigs when total backfat, carcass length and grade index were used as the criteria for assessment.

BIBLIOGRAPHY

- Abernathy, R.P. and R.E. Sewell. 1958. Interrelationships of protein, lysine and energy in diets for growing swine. *J. Animal Sci.* 17:635-639.
- Anderson, G.H. and J.P. Bowland. 1967. Lysine and fat supplementation of weanling pig diets. *Can. J. Animal Sci.* 47:47-55.
- Association of Official Agricultural Chemists. 1965. Official methods of analysis. 10th ed. Washington, D.C.
- Aunan, W.J., L.E. Hanson and R.J. Meade. 1961. Influence of level of dietary protein on liveweight gains and carcass characteristics. *J. Animal Sci.* 20:148-153.
- Baker, D.H., W.W. Clausing, B.G. Harmon, A.H. Jensen and D.E. Becker. 1969a. Replacement value of cystine for methionine for the young pig. *J. Animal Sci.* 29:581-584.
- Baker, D.H., D.E. Becker, H.W. Norton, A.H. Jensen and B.G. Harmon. 1969b. Lysine imbalance of corn protein in the growing pig. *J. Animal Sci.* 28:23-26.
- Bayley, H.S. and J.D. Summers. 1968. Effect of protein level and lysine and methionine supplementation on the performance of growing pigs. *Can. J. Animal Sci.* 48:181-188.
- Becker, D.E., A.H. Jensen, S.W. Terrill and H.W. Norton. 1955. The methionine-cystine need of the young pig. *J. Animal Sci.* 14:1086-1094.
- Bell, J.M. 1965. Nutrient requirements for Canadian Yorkshire swine. V. A study of the lysine and protein requirements of finishing pigs weighing from 100 to 200 lb. *Can. J. Animal Sci.* 45:105-110.
- Bell, J.M. and L.D. Voldeng. 1968. Further observations on lysine and protein requirements of 23 to 89 kilogram pigs. *Can. J. Animal Sci.* 48:251-261.
- Bell, J.M., H.H. Williams, J.K. Loosli and L.A. Maynard. 1950. The effect of methionine supplementation of a soybean oil-purified ration for growing pigs. *J. Nutr.* 40:551-561.
- Blair, R., J.B. Dent, P.R. English and J.R. Raeburn. 1969. Protein, lysine, and feed intake effects. I. Main effects. *J. Agr. Sci.* 72:379-400.
- Blair, R. and P.R. English. 1965. The effect of sex on growth and carcass quality in the bacon pig. *J. Agr. Sci.* 64:169-176.

- Bowland, J.P. 1962. Addition of lysine and/or a tranquilizer to low protein, soybean meal supplemented rations for growing bacon pigs. *J. Animal Sci.* 21:852-856.
- Bowland, J.P. and R.T. Berg. 1959. Influence of strain and sex on the relationship of protein to energy in the rations of growing and finishing bacon pigs. *Can. J. Animal Sci.* 39:102-114.
- Bowland, J.P., H. Bickel, H.P. Pfirter, C.P. Wenk and A. Schürch. 1970. Respiration calorimetry studies with growing pigs fed diets containing from three to twelve percent crude fiber. *J. Animal Sci.* 31:494-501.
- Bowland, J.P. and R.E. Grimson. 1970. Lysine and methionine supplementation of swine and rat diets containing up to three percent urea. *Proc. Internationales Aminosäuren-Symp.* II. Univ. Rostock, DDR, February, 1969. pp. 213-217.
- Bowland, J.P. and J.A. Newell. 1971. Comparison of boars, barrows and gilts fed two levels of protein to market weight. 50th Annual Feeders' Day Report. Dept. of Animal Sci., University of Alberta, Edmonton, Alberta.
- Brinegar, M.J., J.K. Loosli, L.A. Maynard and H.H. Williams. 1950a. The isoleucine requirement for the growth of swine. *J. Nutr.* 42:619-624.
- Brinegar, M.J., H.H. Williams, F.H. Ferris, J.K. Loosli and L.A. Maynard. 1950b. The lysine requirement for the growth of swine. *J. Nutr.* 42:129-138.
- Bruner, W.H., V.R. Cahill, W.L. Robinson and R.F. Wilson. 1958. Performance of barrow and gilt littermate pairs at the Ohio Swine Evaluation Station. *J. Animal Sci.* 17:875-878.
- Bruner, W.H. and L.A. Swiger. 1968. Effects of sex, season and breed on live and carcass traits at the Ohio Swine Evaluation Station. *J. Animal Sci.* 27:383-388.
- Cahilly, G.M. Jr., R.F. Miller, R.F. Kelly and C.C. Brooks. 1963. Effect of various levels of dietary lysine on certain blood phenomena, muscle development and muscle-protein biological value of growing swine. *J. Animal Sci.* 22:726-732.
- Canada Department of Agriculture. 1968. Canada's New Hog Carcass Valuation System. Livestock Division, Production and Marketing Branch, Ottawa.
- Clawson, A.J. 1967. Influence of protein level, amino acid ratio and caloric density of the diet on feed intake and performance of pigs. *J. Animal Sci.* 26:328-333.

- Clawson, A.J., F.R. Barrick and W.W.G. Smart, Jr. 1963. Response of pigs to graded levels of soybean meal and added lysine in ten percent protein diets. *J. Animal Sci.* 22:1027-1032.
- Clawson, A.J., T.N. Blumer, W.W.G. Smart, Jr. and E.R. Barrick. 1962. Influence of energy-protein ratio on performance and carcass characteristics of swine. *J. Animal Sci.* 21:62-68.
- Cordts, R.H. Jr., J.G. Welch and G.W. Van der Noot. 1964. Nitrogen retention in swine fed barley-skim-milk-meat scraps and corn-soybean meal rations. *J. Animal Sci.* 23:953-955.
- Curtin, L.V., J.K. Loosli, J. Abraham, H.H. Williams and L.A. Maynard. 1952. The methionine requirement for the growth of swine. *J. Nutr.* 48:499-508.
- Davey, R.J. and D.P. Morgan. 1969. Protein effect on growth and carcass composition of swine selected for high and low fatness. *J. Animal Sci.* 28:831-836.
- Dent, J.P., R. Blair, P.R. English and J.R. Raeburn. 1970. Protein, lysine and feed intake level effects on pig growth. III. Regression analysis and economic aspects. *J. Agr. Sci.* 75:189-205.
- Devilat, J., W.G. Pond and P.D. Miller. 1970. Dietary amino acid balance in growing-finishing pigs: Effect on diet preference and performance. *J. Animal Sci.* 30:536-543.
- Diggs, B.G., D.E. Becker, S.W. Terrill and A.H. Jensen. 1959. The energy value of various feedstuffs for the young pig. *J. Animal Sci.* 18:1492-1493. (Abstr.)
- Easton, M. 1968. Analysis of Variance CS017. Department of Computing Science, University of Alberta, Edmonton, Alberta.
- Eggert, R.G., H.H. Williams, B.E. Sheffy, E.G. Sprague, J.K. Loosli and L.A. Maynard. 1954. The quantitative leucine requirement of the suckling pig. *J. Nutr.* 53:177-185.
- Ellison, J.S. and K.W. King. 1968. Mechanism of appetite control in rats consuming imbalanced amino acid mixtures. *J. Nutr.* 94:543-554.
- Elvehjem, C.A. 1956. Amino acid imbalance. *Fed. Proc.* 15:965-970.
- Fisher, H., P. Griminger, G.A. Leveille and R. Shapiro. 1960. Quantitative aspects of lysine deficiency and amino acid imbalance. *J. Nutr.* 71:213-220.
- Fredeen, H.T. 1966. Changes in ROP (swine) carcass evaluation. 45th Annual Feeders' Day Report. Dept. of Animal Sci., University of Alberta, Edmonton, Alberta.

- Friend, D.W. and J.M. MacIntyre. 1970. Paired feeding and metabolism trials comparing barrows with gilts. *J. Animal Sci.* 30:931-934.
- Gallo, J.T. and W.G. Pond. 1968. Amino acid supplementation to all-corn diets for pigs. *J. Animal Sci.* 27:73-78.
- Germann, A.F.O. II, E.T. Mertz and W.M. Beeson. 1958. Revaluation of the L-lysine requirement of the weanling pig. *J. Animal Sci.* 17:52-61.
- Greeley, M.G., R.J. Meade, L.E. Hanson and J. Nordstrom. 1964. Energy and protein intakes by growing swine. II. Effects on rate and efficiency of gain and on carcass characteristics. *J. Animal Sci.* 23:816-822.
- Greer, S.A.N., V.W. Hays, V.C. Speer, J.T. McCall and E.G. Hammond. 1965. Effects of level of corn- and barley-base diets on performance and body composition of swine. *J. Animal Sci.* 24:1008-1013.
- Grimble, R.F. and R.G. Whitehead. 1970. Changes in concentration of specific amino acids in the serum of experimentally malnourished pigs. *Br. J. Nutr.* 24:557-564.
- Grimble, R.F. and R.G. Whitehead. 1969. The relationship between an elevated serum amino acid and the development of other biological abnormalities in the experimentally malnourished pig. *Br. J. Nutr.* 23:791-804.
- Grimson, R.E. 1969. Urea, lysine and methionine in swine diets. M.Sc. Thesis. University of Alberta, Edmonton, Alberta.
- Hale, O.M. and B.L. Southwell. 1967. Differences in swine performance and carcass characteristics because of dietary protein level, sex, and breed. *J. Animal Sci.* 26:341-344.
- Harper, A.E. 1964. Amino acid toxicities and imbalances. *Mammalian Protein Metabolism*. Academic Press. New York. Vol. II:87-131.
- Harper, A.E. 1959. Amino acid balance and imbalance. I. Dietary level of protein and amino acid imbalance. *J. Nutr.* 68:405-418.
- Harper, A.E. and U.S. Kumpta. 1959. Amino acid balance and protein requirement. *Fed. Proc.* 18:1136-1142.
- Hicks, C.R. 1964a. *Fundamental Concepts in the Design of Experiments*. Holt Rinehart and Winston. Toronto. pp. 149-156.
- Hicks, C.R. 1964b. *Fundamental Concepts in the Design of Experiments*. Holt Rinehart and Winston. Toronto. pp. 91.

- Jackson, H.D., E.T. Mertz and W.M. Beeson. 1953. Quantitative valine requirement of the weanling pig. *J. Nutr.* 51:109.
- Jurgens, M.H., D.B. Hudman, C.H. Adams and E.R. Peo, Jr. 1967. Influence of a dietary supplement of lysine fed at two levels of protein on growth, feed efficiency and carcass characteristics of swine. *J. Animal Sci.* 26:323-327.
- Kornegay, E.T., V. Mosanghini and R.D. Snee. 1970. Urea and amino acid supplementation of swine diets. *J. Nutr.* 100:330-340.
- Kroening, G.H., W.G. Pond and J.K. Loosli. 1965. Dietary methionine-cystine requirement of the baby pig as affected by threonine and protein levels. *J. Animal Sci.* 24:519-525.
- Kuryvial, M.S. and J.P. Bowland. 1962. Supplemental fat as an energy source in the diets of swine and rats. II. Energy and nitrogen digestibility, nitrogen retention and carcass fat composition. *Can. J. Animal Sci.* 42:33-40.
- Leung, P.M.B., Q.R. Rogers and A.E. Harper. 1968. Effect of Amino acid imbalance on plasma and tissue free amino acids in the rat. *J. Nutr.* 95:483-492.
- Likuski, H.J.A., J.P. Bowland and R.T. Berg. 1961. Energy digestibility and nitrogen retention by pigs and rats fed diets containing non-nutritive diluents and varying in protein level. *Can. J. Animal Sci.* 41:89-101.
- McConnell, J.C., K.M. Barth and S.A. Griffin. 1971. Nutrient digestibility and nitrogen metabolism studies at different stages of growth with fat and lean type swine fed two levels of protein. *J. Animal Sci.* 32:654-657.
- McWard, G.W., D.E. Becker, H.W. Norton, S.W. Terrill and A.H. Jensen. 1959. The lysine requirement of weanling swine at two levels of dietary protein. *J. Animal Sci.* 18:1059-1066.
- Meade, R.J. 1956a. The influence of tryptophan, methionine and lysine supplementation of a corn- soybean oil meal diet on nitrogen balance of growing swine. *J. Animal Sci.* 15:288-296.
- Meade, R.J. 1956b. The influence of methionine supplementation of 12, 14 and 16 percent protein corn- soybean oil meal diets upon nitrogen balance of growing swine. *J. Nutr.* 60:599-608.
- Meade, R.J., W.R. Dukelow and R.S. Grant. 1966. Lysine and methionine additions to corn- soybean oil meal diets for growing swine: Effects on rate and efficiency of gain and carcass characteristics. *J. Animal Sci.* 25:78-82.

- Meade, R.J., J.W. Rust, K.P. Miller, H.E. Hanke, R.S. Grant, L.D. Vermedahl, D.F. Wass and L.E. Hanson. 1969a. Effects of protein level sequence and kind of starter on rate and efficiency of gain of growing swine and on carcass characteristics. *J. Animal Sci.* 29:303-308.
- Meade, R.J. and W.S. Teter. 1956. The influence of L-lysine supplementation of 12, 14 and 16 percent protein corn-soybean oil meal diets upon nitrogen balance of growing swine. *J. Nutr.* 60:609-618.
- Meade, R.J., J.T. Typpo, M.E. Tumbleson, J.H. Goihl and Helmut von der Mehden. 1965. Effects of protein source and level and lysine and methionine supplementation on rate and efficiency of gain of pigs weaned at an early age. *J. Animal Sci.* 24:626-632.
- Meade, R.J., L.D. Vermedahl, J.W. Rust and D.F. Wass. 1969b. Effects of protein content of the diet of the young pig on rate and efficiency of gain during early development and subsequent to 23.5 kg and carcass characteristics and composition of lean tissue. *J. Animal Sci.* 28:473-477.
- Mertz, E.T., J.N. Henson and W.M. Beeson. 1954. Quantitative phenylalanine requirement of the weanling pig. *J. Animal Sci.* 13:927-932.
- Mertz, E.T., D.C. Shelton and W.M. Beeson. 1949. The amino acid requirements of swine, lysine. *J. Animal Sci.* 8:524-531.
- Mitchell, J.R. Jr., D.E. Becker, B.G. Harmon, H.W. Norton and A.H. Jensen. 1968a. Some amino acid needs of the young pig fed a semisynthetic diet. *J. Animal Sci.* 27:1322-1326.
- Mitchell, J.R. Jr., D.E. Becker, A.H. Jensen, B.G. Harmon and H.W. Norton. 1968b. Determination of amino acid needs of the young pig by nitrogen balance and plasma free amino acids. *J. Animal Sci.* 27:1327-1331.
- Mitchell, J.R. Jr., D.E. Becker, A.H. Jensen, H.W. Norton and B.G. Harmon. 1965a. Lysine need of swine at two stages of development. *J. Animal Sci.* 24:409-412.
- Mitchell, J.R. Jr., D.E. Becker, A.H. Jensen, H.W. Norton and B.G. Harmon. 1965b. Caloric density of the diet and the lysine need of growing swine. *J. Animal Sci.* 24:977-980.
- Mulholland, R., E.S. Erwin and R.S. Gordon. 1960. Protein-energy ratios for barrows and gilts marketed at 145 and 195 pounds. *J. Animal Sci.* 19:1278. (Abstr.)
- Munro, H.N. 1970. Free amino acid pools and their role in regulation. *Mammalian Protein Metabolism*. Academic Press. New York. Vol IV: 299-386.

- Nasset, E.S., P.T. Ridley and E.A. Schenk. 1967. Hypothalamic lesions related to ingestion of an amino acid imbalanced diet. *Am. J. Physiol.* 213:645-650.
- National Academy of Sciences. 1968. Nutrient requirements of domestic animals. No. 2. Nutrient requirements of swine. Publ. 1192. Washington, D.C.
- Nielson, H.E., V.W. Hays, V.C. Speer and D.V. Catron. 1963. Lysine supplementation of corn- and barley-base diets for growing-finishing swine. *J. Animal Sci.* 22:454-457.
- Nordstrom, J.W., H.F. Windels, J.T. Typpo, R.J. Meade and W.L. Stockland. 1970. Influence of site of blood withdrawal and stage of fast on concentrations of plasma free amino acids in the growing pig. *J. Animal Sci.* 31:874-884.
- Olsen, E.M., D.C. Hill, J.A. Gray and H.D. Branion. 1959. Effects of dietary protein level on the concentrations of free amino acids in the blood plasma of chicks. *Poul. Sci.* 38:1234. (Abstr.)
- Osborne, T.B. and L.B. Mendel. 1914. Amino acids in nutrition and growth. *J. Biol. Chem.* 17:325-349.
- Pearson, A.M., M.L. Hayenga, R.G. Heifner, L.J. Bratzler and R.A. Merkel. 1970. Influence of various traits upon live and carcass value for hogs. *J. Animal Sci.* 31:318-322.
- Peng, Y. and A.E. Harper. 1970. Amino acid balance and food intake: Effect of different dietary amino acid patterns on the plasma amino acid pattern of rats. *J. Nutr.* 99:429-437.
- Puchal, F., V.W. Hays, V.C. Speer, J.D. Jones and D.V. Catron. 1962. The free blood plasma amino acids of swine as related to the source of dietary proteins. *J. Nutr.* 76:11-16.
- Rechcigl, M. Jr., J.K. Loosli, D.J. Horvath and H.H. Williams. 1956. Histidine requirement of baby pigs. *J. Nutr.* 60:619-629.
- Reimer, D. and R.J. Meade. 1964. Barley rations for swine. I. Influence of source and level of dietary protein on rate and efficiency of gain of growing swine. *J. Animal Sci.* 23:392-396.
- Reimer, D., R.J. Meade and R.S. Grant. 1964. Barley rations for swine. III. Lysine and methionine supplementation: Effects on rate and efficiency of gain, and on carcass characteristics. *J. Animal Sci.* 23:404-408.
- Richmond, R.J. and R.T. Berg. 1971. Tissue development in swine as influenced by liveweight, breed, sex and ration. *Can. J. Animal Sci.* 31:494-501.

- Robinson, D.W. and D. Lewis. 1964. Protein and energy nutrition of the bacon pig. II. The effects of varying the protein and energy levels in the diets of 'finishing' pigs. *J. Agr. Sci.* 63:185-190.
- Robinson, D.W., J.T. Morgan and D. Lewis. 1964a. Protein and energy nutrition of the bacon pig. *J. Agr. Sci.* 62:369-376.
- Robinson, D.W., J.T. Morgan and D. Lewis. 1964b. Protein and energy nutrition of the bacon pig. III. The effect of reducing the protein content of pig diets at different liveweights. *J. Agr. Sci.* 63:409-414.
- Rogers, Q.R., R.I. Tannous and A.E. Harper. 1967. Effect of excess of leucine on growth and food selection. *J. Nutr.* 91:561-572.
- Rutledge, E.A., L.E. Hanson and R.J. Meade. 1961. Protein requirements of suckling age pigs. *J. Animal Sci.* 20:142-147.
- Seerley, R.W., G.E. Poley and R.C. Wahlstrom. 1964. Energy and protein relationship studies with growing-finishing swine. *J. Animal Sci.* 20:820-823.
- Sewell, R.F., J.K. Loosli, L.A. Maynard, H.H. Williams and B.E. Sheffy. 1952. The quantitative threonine requirement of the suckling pig. *J. Nutr.* 49:435-441.
- Seymour, E.W., V.C. Speer, V.W. Hays, D.W. Mangold and T.E. Hazen. 1964. Effects of dietary protein level and environmental temperature on performance and carcass quality of growing-finishing swine. *J. Animal Sci.* 23:375-379.
- Shapiro, R. and H. Fisher. 1962. Role of protein reserves in the protein nutrition of the growing animal. *Fed. Proc.* 21:395. (Abstr.)
- Shelton, D.C., W.M. Beeson and E.T. Mertz. 1951. Quantitative DL-tryptophan requirement of the weanling pig. *J. Animal Sci.* 10:73-79.
- Skitsko, P.J. and J.P. Bowland. 1970a. Performance of gilts and barrows from three breeding groups marketed at three liveweights when offered diets containing two levels of digestible energy for a limited period per day. *Can. J. Animal Sci.* 50:161-170.
- Skitsko, P.J. and J.P. Bowland. 1970b. Energy and nitrogen digestibility and retention by pigs as influenced by diet, sex, breeding group and replicate. *Can. J. Animal Sci.* 50:685-691.
- Smith, G.H. and D. Lewis. 1966. Arginine in poultry nutrition. 3. Agent and target in amino acid interactions. *Br. J. Nutr.* 20:621-631.

- Soldevila, M. and R.J. Meade. 1964. Barley rations for swine. II. The influence of L-lysine and DL-methionine supplementation of barley-soybean meals upon rate and efficiency of gain and upon nitrogen retention of growing swine. *J. Animal Sci.* 23:397-403.
- Standish, J.F. and J.P. Bowland. 1967. Effects of varying dietary energy, protein and amino acid levels on growth, nutrient digestibility and serum protein levels of early weaned pigs. *Can. J. Animal Sci.* 47:77-83.
- Steel, R.G.D. and J.H. Torrie. 1960. Principles and Procedures of Statistics with Special Reference to Biological Sciences. McGraw-Hill Book Company Inc. New York, N.Y.
- Stockland, W.L. and R.J. Meade. 1970. Meat and bone meal as sources of amino acids for the growing rat: use of a reference diet to predict amino acid adequacy by levels of plasma free amino acids. *J. Animal Sci.* 31:1156-1167.
- Stockland, W.L., R.J. Meade and J.W. Nordstrom. 1971. Lysine, methionine and tryptophan supplementation of a corn-meat and bone meal diet for growing swine. *J. Animal Sci.* 32:262-267.
- Stockland, W.L., R.J. Meade and J.W. Nordstrom. 1970. Meat and bone meals as sources of amino acids for growing swine: use of a reference diet to predict amino acid adequacy by plasma levels. *J. Animal Sci.* 31:1142-1155.
- Typpo, J.T., R.J. Meade, J.W. Nordstrom and W.L. Stockland. 1970. Influence of time of fast on concentrations of free amino acids in plasma and total amino acids in liver protein of young swine. *J. Animal Sci.* 31:885-891.
- Units of Weight and Measure, National Bureau of Standards. 1960. Definitions and tables of equivalents. United States Department of Commerce. Publ. 233. Washington, D.C.
- Vipperman, P.E. Jr., C.C. Brooks, R.F. Kelly, P.P. Graham and H.R. Thomas. 1963. Effect of dietary lysine level on muscle size and composition in swine. *J. Animal Sci.* 22:674-678.
- Wagner, G.R., A.J. Clark, V.W. Hays and V.C. Speer. 1963. Effect of protein-energy relationships on the performance and carcass quality of growing swine. *J. Animal Sci.* 22:202-208.
- Wahlstrom, R.C., A.R. Taylor and R.W. Seerley. 1970. Effects of lysine in the drinking water of growing swine. *J. Animal Sci.* 30:368-373.
- Waldern, D.E. 1964. Influence of energy and protein level in rations for finishing market pigs on performance and carcass characteristics. *Can. J. Animal Sci.* 44:168-173.

- Welch, J.G., R.H. Cordts and G.W. Van der Noot. 1966. Effect of lysine, methionine and tryptophan supplementation upon nitrogen retention in barrows. J. Animal Sci. 25:806-808.
- Windels, H.F., R.J. Meade, J.W. Nordstrom and W.L. Stockland. 1971. Influence of source and level of dietary protein on plasma free amino acid concentrations in growing swine. J. Animal Sci. 32: 268-276.
- Wyllie, D., V.C. Speer, R.C. Ewan and V.W. Hays. 1969. Effects of starter protein level on performance and body composition of pigs. J. Animal Sci. 29:433-438.
- Young, L.G., G.C. Ashton, R.P. Forshaw and R.H. Ingram. 1968. Relationship of dietary protein levels to performance and carcass merit of market swine. Can. J. Animal Sci. 48:71-81.

APPENDIX A

Table i. - Means for average daily feed (ADF) in kg/day, average daily gain (ADG) in kg/day and efficiency of feed conversion (CONV) in kg/day where significant interactions occurred

Experiments I and II combined

<u>Factor¹</u>	<u>ADF-Starter</u> *	<u>ADF-Grower</u> *	<u>ADG-Finisher</u> *	<u>ADG-Overall</u> *
MEI	1.02	2.29	.87	.66
FEI	1.15	2.29	.86	.68
MEII	1.20	2.49	.94	.68
FEII	1.20	2.17	.85	.65

<u>Factor²</u>	<u>CONV-Overall</u> **	<u>ADF-Grower</u> *
MT1	3.38	2.79
MT2	3.24	2.59
MT3	3.19	2.40
MT4	3.49	1.80
FT1	3.09	2.46
FT2	3.19	2.34
FT3	3.11	2.24
FT4	3.49	1.87

Experiment III

<u>Factor³</u>	<u>ADG-Overall</u> *
MT1	.65
MT2	.70
MT3	.66
MT4	.61
MT5	.65
FT1	.63
FT2	.54
FT3	.65
FT4	.55
FT5	.63

¹ Experiment (EI, EII) x Sex (M, F)

² Treatment (T1, T2, T3, T4) x Sex (M, F)

³ Treatment (T1, T2, T3, T4, T5) x Sex (M, F)

Table ii. - Means for carcass data where significant interactions occurred

Experiment IFactor¹Lean area ham/
ham weight
sq cm/kg

	*
MT1	14.4
MT2	15.6
MT3	14.8
MT4	14.1
MT5	16.8
FT1	16.1
FT2	15.6
FT3	15.2
FT4	15.1
FT5	15.1

Experiment II

<u>Factor²</u>	<u>Total backfat cm</u>	<u>Loin area sq cm</u>	<u>Carcass length cm</u>	<u>Carcass weight kg</u>	<u>NROP</u>	<u>OROP</u>
	*	*	*	**	*	*
LYT1	10.9	29.1	75.6	67.4	68.1	77.5
HYT1	10.4	28.6	77.9	69.8	67.1	76.9
LYT2	10.8	29.3	76.3	68.1	67.9	77.6
HYT2	10.3	27.5	78.2	71.9	67.5	77.0
LYT3	10.2	28.6	75.8	65.3	68.7	78.6
HYT3	9.9	28.9	78.5	70.5	68.1	78.1
LYT4	12.2	26.8	75.9	71.5	64.8	74.8
HYT4	9.4	22.6	73.5	61.5	68.7	77.9
LYT5	10.5	28.4	74.7	67.8	67.6	77.3
HYT5	10.3	30.6	76.1	68.3	68.6	77.9
LYT6	10.4	28.2	74.8	64.9	68.8	77.6
HYT6	10.3	31.0	77.0	69.7	68.9	78.1

Experiments I and II CombinedFactor³Lean in ham face (%)

	*
MT1	46.6
MT2	49.9
MT3	49.0
MT4	47.5
FT1	53.8
FT2	51.8
FT3	53.2
FT4	48.2

-
- ¹ Treatment (T1, T2, T3, T4, T5) x Sex (M, F)
² Breed (LY, HY) x Treatment (T1, T2, T3, T4, T5, T6)
³ Treatment (T1, T2, T3, T4) x Sex (M, F)

Table iii. - Experiment II - Means for metabolism data where significant interactions occurred on a dry matter basis

<u>Factor¹</u>	<u>Daily feed</u>	<u>N-retention of digestible N (%)</u>	<u>ME as % of DE</u>
	*	*	*
MLY	554	55.9	98.5
MHY	610	72.0	97.9
FLY	680	68.9	97.7
FHY	551	63.1	97.8

<u>Factor²</u>	<u>ME as % of DE</u>
LYT1	97.7
HYT1	97.7
LYT2	98.1
HYT2	97.0
LYT3	97.8
HYT3	98.3
LYT4	98.4
HYT4	98.8
LYT5	98.5
HYT5	97.5
LYT6	98.3
HYT6	97.9

¹ Breed (LY, HY) x Sex (M, F)

² Breed (LY, HY) x Treatment (T1, T2, T3, T4, T5, T6)

APPENDIX B

Table i. Experiment I - Mean squares - feed and growth data¹

Factor	df	Average Daily Feed - (ADF)			
		Starter	Grower	Finisher	Overall
Treatment (T)	4	.0762**	.7440**	.1402	.0914*
Replicate	1	.0156	.2101 ^o	.1514	.0884 ^o
Sex (S)	1	.0845	.0031	.1960	.0000
TS	4	.0063	.0345	.0315	.0114
Error	9	.0054	.0484	.0669	.0218
Total	19				

Factor	df	Average Daily Gain - (ADG)			
		Starter	Grower	Finisher	Overall
Treatment (T)	4	.0556**	.0713**	.0066	.0180**
Replicate	1	.0051	.0013	.0022	.0024
Sex (S)	1	.0157	.0000	.0048	.0003
TS	4	.0002	.0028	.0030	.0021
Error	9	.0021	.0046	.0041	.0022
Total	19				

Factor	df	Feed Conversion (CONV)			
		Starter	Grower	Finisher	Overall
Treatment (T)	4	.8009 ^o	.1750**	.5548**	.0344 ^o
Replicate	1	.0001	.3251**	.3809*	.0732*
Sex (S)	1	.0065	.0186	.0541	.0396 ^o
TS	4	.2016	.0372	.0136	.0192
Error	9	.2407	.0182	.0615	.0101
Total	19				

¹ See Tables 7, 8 and 9

Table ii. Experiment II - Mean squares - feed and growth data¹

Factor	df	STARTING PERIOD ²		
		ADF	ADG	CONV
Treatment (T)	5	.0139	.0671**	2.1052**
Replicate	1	1.4491**	.3040**	.2745
Sex (S)	1	.0000	.0040	.0075
TS	5	.0039	.0008	.0690
Breed (B)	1	.0091	.0091*	.1530
BT	5	.0035	.0032	.3361
BS	1	.0000	.0004	.0653
BTS	5	.0056	.0010	.0313
Error	23	.0142	.0017	.1842
Total	47			

¹ See Tables 10, 11 and 12

² For growing and finishing periods, see page vi

Table ii. (cont'd)

GROWING AND FINISHING PERIODS

Factor	df	Average Daily Feed - (ADF)		
		Grower	Finisher	Overall
Treatment (T)	5	.2131*	.1144*	.0175*
Replicate	1	.5643**	.1751*	.1561**
Sex (S)	1	.8067**	.9322**	.1442**
TS	5	.0523	.0044	.0019
Error	11	.0417	.0223	.0037
Total	23			

Factor	df	Average Daily Gain - (ADG)		
		Grower	Finisher	Overall
Treatment (T)	5	.0235**	.0094 ^o	.0094**
Replicate	1	.0057 ^o	.0308*	.0081**
Sex (S)	1	.0234**	.0561**	.0054**
TS	5	.0004	.0019	.0002
Error	11	.0017	.0034	.0002
Total	23			

Factor	df	Feed Conversion (CONV)		
		Grower	Finisher	Overall
Treatment (T)	5	.2860**	.1822**	.1210**
Replicate	1	.0580	.0294	.0054
Sex (S)	1	.0131	.0011	.0523*
TS	5	.0197	.0370	.0113
Error	11	.0131	.0289	.0055
Total	23			

Table iii. Experiments I and II combined - Mean squares - feed and growth data for the starting period¹

Factor	df	ADF	ADG	CONV
Treatment (T)	4	.0569**	.0901**	1.9467**
Experiment (E)	1	.1476	.0141	.0010
TE	4	.0256*	.0028	.1269
Replicate/E	2	.2951**	.0642**	.0505
Sex (S)	1	.0416*	.0156**	.0012
TS	4	.0050	.0015	.0828
ES	1	.0429*	.0027	.0063
ETS	4	.0037	.0010	.1609
Error	18	.0059	.0012	.1600
Total	39			

¹ See Tables 13, 14 and 15

Table iv. Experiments I and II combined - Mean squares - feed and growth data for the growing and finishing periods¹

Factor	df	Average Daily Feed - (ADF)		
		Grower	Finisher	Overall
Treatment (T)	3	.9223**	.2414*	.0592**
Experiment (E)	1	.0145	.3081	.0882
TE	3	.0392*	.0193	.0079
Replicate/E	2	.3138**	.1792*	.0785*
Sex (S)	1	.2211*	.6161**	.0392
TS	3	.0604	.0169	.0126
ES	1	.1985*	.0820	.0512
ETS	3	.0323	.0235	.0043
Error	14	.0369	.0506	.0142
Total	31			

Factor	df	Average Daily Gain - (ADG)		
		Grower	Finisher	Overall
Treatment (T)	3	.0950**	.0107*	.0278**
Experiment (E)	1	.0001	.0075	.0008
TE	3	.0015	.0072	.0002
Replicate/E	2	.0060	.0106*	.0043 ^o
Sex (S)	1	.0061	.0270**	.0003
TS	3	.0019	.0016	.0003
ES	1	.0066	.0132*	.0058*
ETS	3	.0022	.0033	.0007
Error	14	.0029	.0030	.0013
Total	31			

Factor	df	Conversion - (CONV)		
		Grower	Finisher	Overall
Treatment (T)	3	.4316**	.6356**	.1791**
Experiment (E)	1	.0055	1.1628	.1845
TE	3	.0552**	.0749	.0469**
Replicate/E	2	.0893**	.2790**	.0247**
Sex (S)	1	.0055	.0496	.0871**
TS	3	.0241	.0283	.0325**
ES	1	.0003	.0242	.0004
ETS	3	.0128	.0265	.0009
Error	14	.0063	.0457	.0006
Total	31			

¹ See Tables 13, 14 and 15

Table v. Experiment III - Mean squares - feed and growth data

Factor	df	Average Daily Feed - (ADF)			Overall
		Starter	Grower	Finisher	
Treatment (T)	4	.1231	.1970	.6191	.2335
Replicate	1	.0168	.0116	.4796	.1188
Error	4	.0489	.0917	.2844	.0590
Total	9				

Factor	df	Average Daily Gain - (ADG)			Overall
		Starter	Grower	Finisher	
Treatment (T)	4	.0669	.2050*	.0174	.0177*
Replicate	1	.0146	.0938	.0266	.0162 ^o
Sex (S)	1	.0058	.0684	.2761**	.0806**
TS	4	.0448	.0695	.0231	.0171*
Error	9	.0457	.0492	.0105	.0046
	19				

Factor	df	Feed Conversion - (CONV)			Overall
		Starter	Grower	Finisher	
Treatment (T)	4	.0267	.5456	.1621	.0548
Replicate	1	.0023	.4000	.0397	.0212
Error	4	.0207	.5974	.1206	.0359
	9				

¹ See Tables 16, 17 and 18

Table vi. Experiment I - Mean squares - slaughter age and carcass data¹

Factor	df ²	Slaughter age	Carcass weight	Dressing %	Total backfat	Loin area	Ham/ carcass	Lean in ham face	Lean area ham/ham weight	Carcass length	NROP	OROP	Grade index
Treatment (T)	4	1831.2**	21.956	1.3026	.1433	.3190	1.0942°	49.855°	.0230°	.7411	9.7109	5.0939	6.9250
Replicate	1	.6125	19.012	8.5150	.0005	3.4653**	.4104	169.48**	.0646*	3.5280	17.672	5.6550	19.012
Sex (S)	1	86.112	23.112	2.4500	3.7845**	.8262°	3.9118°	164.91**	.0068	10.225**	60.066**	47.5730**	112.81**
TS	4	89.144	82.664	1.3935	.3376	.0825	2.6185	58.197°	.0307*	.9808	11.7680	3.6752	20.000
Error	66	89.3515	93.8151	3.4249	.2395	.2383	1.0390	23.2831	.0105	1.3207	7.1162	5.0005	10.2251
Total	76												

1 See Table 19

2 Carcass data was not available on three pigs (treatments 2, 4 and 5) so error df was reduced by 3 to 66

Table vii. Experiment II - Mean squares - slaughter age and carcass data¹

Factor	df ²	Slaughter age	Carcass weight	Dressing %	Total backfat	Loin area	Ham/carcass	Lean in ham face	Lean area ham/ham weight	Carcass length	NROP	OROP	Grade index
Treatment (T)	5	785.52**	108.57	2.7292	.1812	1.2694**	.2489	44.009°	.0091	2.6527**	8.3032	7.5198°	31.592°
Replicate	1	41.344	1.5000	.7246	.8438*	.3553	6.7841**	200.54**	.0128	.1350	39.373*	33.358*	8.1667
Sex (S)	1	341.26*	35.042	7.7628°	3.4504**	2.8153**	16.684**	221.53**	.0017	3.4502*	86.453**	133.13**	28.167
TS	5	111.89	93.942	5.4684	.0504	.0279	.3350	27.344	.0197	1.4039	1.9482	.6059	14.117
Breed (B)	1	237.51°	150.00	9.2751°	2.1600**	.0204	2.5480*	15.884	.0130	6.7204**	5.9104	4.9641	112.67*
BT	5	17.985	631.50**	2.8308	.6495	.6326*	.2823	35.115	.0216	2.1834*	13.250*	8.1962*	18.867
BS	1	8.7604	100.04	.1601	.0038	.0009	1.5453	53.566	.0321	1.5000	2.8221	.4387	15.042
BTS	5	25.635	116.34	1.1738	.1888	.2577	.7072	4.9134	.0095	1.8285	.8451	2.2313	13.142
Error	70	60.252	155.60	2.7256	.2166	.2574	.6352	19.505	.0115	.7807	5.6443	3.3042	14.4191
Total	94												

¹ See Table 20² Carcass data was not recorded for one pig (treatment 2) so error df was reduced by 1 to 70

Table viii. Experiments I and II combined - Mean squares - slaughter age and carcass data¹

Factor	df ²	Slaughter age	Carcass weight	Dressing %	Total backfat	Loin area	Ham/carcass	Lean in ham face	Lean area ham/ham weight	Carcass length	NROP	OROP	Grade index
Treatment (T)	3	2448.8**	98.927	1.8572	.3051	.9781**	.7723	69.397*	.0068	2.4755	9.1037	9.6919 ^o	44.094*
Experiment (E)	1	279.07 ^o	231.12	67.655*	.4050	3.9516	.0741	25.292	.1131	.3613	9.1478	.5292	.7813
TE	3	41.091	86.063	2.2644	.1527	.7284*	.9099	30.863	.0086	1.8602	4.3685	7.6202	13.177
Replicate/E	2	15.6639	39.766	1.9188	.2195	1.0958*	2.6386*	179.94**	.0198	1.8771	17.6556 ^o	16.5679*	15.0625
Sex (S)	1	228.45*	6.125	2.9761	6.3903**	2.0024**	6.2395**	395.43**	.0137	16.245**	124.54**	122.72**	91.125*
TS	3	194.42 ^o	182.27	5.3261	.2218	.0725	.1071	65.975*	.0211	2.3165	9.9412	2.8384	45.479 ^o
ES	1	33.008	69.031	1.0512	.0013	.0930	2.7848 ^o	9.3961	.0321 ^o	.2279	.0038	7.6685	18.000
ETS	3	106.03	69.052	1.9480	.2306	.0526	1.4531	19.475	.0216	.1055	7.4382	2.3556	2.7708
Error	107	68.706	161.62	3.2419	.2704	.2326	.7791	22.009	.0192	1.2309	6.5423	4.5070	14.050
Total	124												

¹ See Table 21² Carcass data was not available for three pigs (Experiment I, treatment 2; Experiment I, treatment 4 and Experiment II, treatment 2) so error df was reduced by 3 to 107

Table ix. Experiment III - Mean squares - slaughter age and carcass data¹

Factor	df	Slaughter age	Carcass weight	Dressing %	Total backfat	Grade index
Treatment (T)	4	140.57	5.050	.2420	.0689	1.4546
Replicate	1	174.05	7.200	1.9220	.0061	3.4444
Sex (S)	1	551.25*	45.000 ^o	6.0500*	.8282**	48.3600*
TS	4	121.62	2.750	.2575	.0151	1.7630
Error	9	61.61	9.200	.7787	.0651	5.3545
	19					

¹ See Table 22

Table x. Experiment II - Mean squares - metabolism data for protein digestibility and N-retention¹

Factor	df	Daily feed	N digested (g)	Protein digestibility (%)	N-retention of gross N (%)	N-retention of gross N (%)	N-retention of digestible N (%)
Treatment (T)	5	1660.3	2018.0*	32.020	544.59	70.337	93.466
Sex (S)	1	6700.0	.3267	43.202	44.010	.0104	25.420
TS	5	3222.1	62.547	1.3767	26.875	3.7334	5.2164
Breed	1	7884.4	5.0419	86.640	52.511	293.30	158.62
BT	5	2049.5	82.053	40.775	92.555	94.665	74.372
BS	1	50876.0*	2090.7 ₀	51.042	2937.1 ₀	633.45 ₀	709.59*
Error	5	4025.9	366.95	42.271	519.22	113.63	95.575
Total			23				

¹ See Table 23

Table xi. Experiment II - Mean squares - metabolism data for digestible and metabolizable energy¹

Factor	df	DE/kg feed	digestibility %	ME/kg feed	ME as % of DE	Calculated ME
Treatment (T)	5	265690*	44.470	269770*	.4910*	244840.0*
Sex (S)	1	35190	21.470	44634	1.0417*	32413.0
TS	5	7667	4.436	58246	.4117*	7049.1
Breed	1	51615	28.821	43776	.4267 ^o	47348.0
BT	5	47054	28.814	47519	.5106*	43295.0
BS	1	30745	19.984	16801	.8067*	28291.0
Error	5	47231	29.408	48050	.0647	43497.0
	23					

¹ See Table 24

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